TRAINING PROGRAMME
ON
ENERGY CONSERVATION
FOR
BHARAT PUMPS AND COMPRESSORS LTD.

Conducted by

TATA ENERGY RESEARCH INSTITUTE
NEW DELHI-110003

JANUARY 1988

TRAINING PROGRAMME ON ENERGY CONSERVATION
FOR
BHARAT PUMPS AND COMPRESSORS LIMITED

READING MATERIAL

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TATA ENERGY RESEARCH INSTITUTE

NEW DELHI

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Time Table

Training Programme on Energy Conservation

at Bharat Pumps and Compressors Limited

Naini, Allahabad

January 7, 1988

9:30 - 9:45 am	Inaugural Session
9:45 - 10:30 am	Why Energy Management ? by Mr. G. Sambasivan
10:30 - 11:15 am	How to Manage Energy Management Programme by Mr. V.S. Kothari
11:15 - 12:00 noon	Energy Audits by Mr. G. Sambasivan
12:00 - 12:45 pm	Fuel Economy in Industrial Furnaces by Mr. H. Harish
12:45 - 1:30 pm	Lunch
1:30 - 2:30 pm	Electrical Energy Conservation by Mr. S. Sabharwal
2:30 - 3:15 pm	Energy Conservation Concepts for Diesel Generators by Mr. H. Harish
3:15 - 4:00 pm	Short-Term Energy Conservation Measures and Housekeeping by Mr. V.S. Kothari
4:00 - 4:45 pm	Films/Discussion
4:45 - 5:00 pm	Programme Evaluation

January 8, 1988

9:30 - 9:45 am	Why Energy Conservation by Mr. G. Sambasivan
9:45 - 10:45 am	Electrical Energy Conservation Practices by Mr. S. Sabharwal
10:45 - 11:30 am	Efficient Operation of Furnaces by Mr. H. Harish
11:30 - 12:30 pm	Housekeeping Measures - I by Mr. G. Sambasivan
12:30 - 1:15 pm	Lunch
1:15 - 2:00 pm	Housekeeping Measures - II by Mr. G. Sambasivan
2:00 - 2:45 pm	Diesel Conservation by Mr. H. Harish
2:45 - 3:45 pm	Films/Discussion
3:45 - 4:15 pm	Programme Evaluation

India's Energy Scene - Supply and Demand Patterns by

K.L. Puri, Advisor, Energy Conservation, Government of India

Background Material for
"Why Energy Conservation"

Reading Material for
Training Programme on Energy Conservation
at Bharat Pumps and Compressors Limited
Naini, Allahabad
January 7-8, 1988

Tata Energy Research Institute
7 Jor Bagh, New Delhi 110 003

INDIA'S ENERGY SCENE -
SUPPLY AND DEMAND PATTERNS

By

K.L. Puri
Advisor, Energy Conservation
Government of India

INTRODUCTION

A high rate of growth in consumption, increasing supply of energy forms, though not in pace with demand, and growing reliance on non-renewable sources of energy (especially oil) characterize India's energy scene.

Increased quantities of coal is being consumed by the thermal power stations, whereas the coal consumption has been more or less stable in the industrial sector, and it has shown a decrease in domestic and transportation sectors. The increase in oil consumption is mainly in the transportation and industrial sectors. Electricity consumption in the domestic/commercial and agricultural sectors has shown rapid growth whereas in the industrial sector, the growth rate has been moderate. On one hand large investments are poured into the energy supply sector (the VII Plan allocation for the energy sector is over 35 per cent of the total plan allocation to increase energy supply), on the other the energy demand has been growing more rapidly. Contribution from renewable energy sources (excluding traditional fuels) still remains a small fraction of the total energy consumed in the country. However, the potential remains high, and renewable energy can be expected to make a large impact on our energy scene in future.

Common sense demands that a country which is affected by serious energy shortages must, even as it increases the supply of energy by all the means available to it, also ensure that it makes the most efficient use of whatever energy it consumes.

However, energy conservation has not so far played a significant role in reducing our energy requirements. The potential for conservation remains high in industry, transport, agriculture and domestic sectors, in that order. With proper policies and education, energy conservation is expected to have a major impact on our energy scene in future. Energy conservation is a necessity, and not an option any more. Of course, the challenges are many. Fortunately, the opportunities also appear innumerable.

This paper presents India's supply and demand patterns and trends only for the commercial energy sources, viz., coal, oil, gas and electricity.

ENERGY SUPPLY AND DEMAND PATTERN

India's energy supply sector is characterized by ever-increasing investment requirements, low productivity/plant load factors and increasing import of oil. On the demand side, there is an increasing reliance on oil, especially for transportation, low conversion efficiencies and a general lack of awareness about conserving energy. The consumption trend is not consistent with the level and mix of energy resource endowments of our country.

The primary commercial fuels are coal, oil and natural gas, and the secondary source of energy is in the form of electricity. In this section, the energy supply trends and the consumption patterns of these commercial energy sources are looked at in some detail.

Coal

India is the world's sixth largest coal producer with a coal production of about 165 million tonnes in 1986-87. Coal is essential to India's economic progress, providing nearly 55 per cent of India's estimated commercial energy consumption. India's coal reserves are as large as 158 billion tonnes compared to about 17 billion tonnes of prognosticated oil plus oil equivalent of natural gas resources. Coal is expected to play a critical role in providing a large share of commercial energy supplies for next several decades. Coking coal resources constitute only 18 per cent of the total resources, the balance 82 per cent being non-coking coals.

The pattern of coal consumption has changed significantly during the last many decades. The railways were the largest consumer of coal in the past, but have adopted a deliberate policy of reducing their consumption by phasing out steam locos. At present thermal power stations are the largest consumer of coal (approximately 49 per cent in 1985-86) and the consumption by this sector will continue to grow in future. Steel industry is the second largest consumer. In 1984-85, about 76.7 per cent of the total coal despatches were consumed by four major sectors namely, power plants, steel industry, railways and cement industry. The balance quantity was consumed by the organized industrial sector, including a large number of small brick industries, small-scale industries, etc. Table 1 shows the consumption pattern for coal in 1985-86.

Table 1

Coal Consumption Pattern in 1985-86

Sector	Coal Consumption	
	Million tonnes	Percentage
Power	75.1	48.7
Industries other than iron and steel	31.0	20.1
Iron & Steel	24.5	15.9
Railways	9.1	5.9
Cement	7.9	5.1
Collieries	4.1	2.7
Softcoke/LTC	2.3	1.5
Export	0.2	0.1
Total	154.2	100.0

Oil and Gas

India is a net oil importer, and its bill has increased considerably since early 1960s. The increases in quantity of imported oil has occurred despite achieving greater self-sufficiency in oil supplies, from a mere six per cent in 1960/61 to about 30-40 per cent during the 1970s. However, the net oil import bill is reported to have reduced substantially since 1980/81; this is largely due to :

(i) a rapid increase in indigenous crude production as self-sufficiency in oil supplies increased to over 70 per cent in 1985/86

(ii) falling oil prices in the international market.

The net oil imports reached a peak value of 23.5 million tonnes(Mt) in 1980-81. It dropped steadily to 12.3 Mt in 1984/85, but again started going up to 16.52 Mt in 1985/86, for a total value of Rs. 4,315 crores. In 1987/88 fiscal year, the imports oil bill is expected to be over Rs. 4,500 crores.

1/ Figures for 1985/86 are provisional

Indigenous production of oil and natural gas has increased from 6.82 Mt and 1445 million cu.m (M cu.m) in 1970/71 to 30.17 Mt and 8134 M cu.m in 1985/86 respectively. The net crude oil and refined products imports totalled over 16.52 Mt in 1985/86 and is expected to increase further.

Despite the increase in oil prices between 1973 and 1983, per capita consumption of oil in India has gone up, as is the case for most other countries of the region. It grew at an average annual growth rate of 2.3 % between 1973 and 1983, i.e., from 43 tonnes of oil equivalent (toe) per 1,000 persons to 54 toe per 1000 persons.

There appears to be a certain inevitability in the increase of oil consumption in the Indian economy, particularly since there have been partial failures in the supply of other forms of energy. There is, nevertheless, considerable scope for conservation measures, which need to be taken in hand urgently if we are to effectively manage our growing dependence on oil and oil products, and their imports.

The consumption of petroleum products increased rapidly from about 17.9 Mt in 1970/71 to 40.49 Mt in 1985/86. This was partly due to a rise in economic activity. However, persistent shortages in coal supply and utility electricity - particularly during the past ten years - have resulted in an increased demand for refined products. Furthermore, certain pricing policies, such as subsidizing kerosene, have also contributed to a rise in kerosene demand for household cooking, by making soft-coke production unprofitable. Other reasons, such as a rising share of road traffic, rapidly increasing use of diesel in buses and trucks, dieselization of railways, increasing reliance on tractors for land preparation in agriculture, etc., also contributed to a rapid rise in the consumption of petroleum products.

The sectoral consumptions of petroleum products in 1985-86 are shown in Table 2.

The natural gas consumption in the country has gone up from about 650 M cu.m in 1970/71 to 4,950 M cu.m in 1985/86. The bulk of the consumption was in the industrial sector, which accounted for 60 per cent of the total consumption, i.e., 2,970 M cu.m. The gas production has already touched 10 billion cu.m this year, and the consumption now represents more than 75 per cent of the total gas production. There is an increase in use of gas for fertilizer production. Plans are already under way for expanding the use of gas to make petrochemicals, for power production, and to produce liquified petroleum gas for domestic use. However, the current gas use pattern points to the need for policies, strategies and programmes for synchronization of all activities connected with natural gas utilization.

Table 2

Sectoral Consumption of Petroleum Products, 1985-86 (Provisional)

	Thousand tonnes	Percentage
Industrial Sector	12136	30.2
Transport Sector		
i) Road Transport	13236	32.8
ii) Air Transport	1593	3.9
iii) Railways	1258	3.1
iv) Water Transport	416	1.0
Residential Sector	7313	18.1
Agricultural Sector	300	0.7
Other Sectors	4134	10.2
Total	40386	100.0

Electricity

India's experience in power development, despite many pitfalls and weaknesses, displays a magnitude of growth almost unparalleled in the comity of the third world nations. The power consumption per capita in 1985-86 was approximately 170 kWh, as compared to about 18 kWh in 1950-51. Given India's rapid increase in population, this growth per capita was remarkable, and it was achieved by building up power generation capacity from 1,360 MW at the time of independence to over 48,500 MW in 1986-87. The total power generation increased from 4.1 billion kWh in 1947 to about 188 billion kWh in 1986-87. The overall growth has been accompanied by significant changes in the mix of consumers on the demand side as well as the mix of generation sources on the supply side.

The plant load factor (PLF) in the thermal sector, which represents 60 per cent of the total power generation capacity, has remained rather low, i.e., at 53.4 per cent in 1986-87. However, the NTPC units have been doing very well. They operated their plants at an overall PLF of 79.6 per cent in 1986-87. The shortfall in meeting the demand at present is about 9.4 per cent. Unless strenuous efforts are made to improve the PLF, especially in the thermal power stations, the gap is expected to widen further. Many of the old power plants require modernization, and in general the State Electricity Boards have to be run more professionally and in an autonomous manner.

The gap between electricity demand and supply has shown a disturbing trend. In 1984/85, the gap was 6.7 per cent, in 1985/86, it was 7.9 per cent and in 1986/87, it was 9.4 per cent. It is not possible to bridge this gap by addition of new capacities alone, which in any case is limited by resource constraints. The only way to reduce the gap is to adopt an integrated approach, i.e., give equal attention to new generating capacities, renovation and modernization of older units, improved operation and maintenance practices, and energy conservation measures to achieve higher energy efficiencies. Particular attention should be paid to reduction in transmission and distribution losses, and electricity consumption in power plant auxiliaries.

Table 3 presents the trends in electricity consumption in different economic sectors from 1950 to 1984/85. While the consumption in every sector has gone up manyfold, the share of consumption of the agricultural sector has shown a more remarkable increase than the other sectors.

Industrial Sector

The industrial sector in India has traditionally been the largest consumer of commercial energy in the Indian economy. In 1985-86, it has been estimated that about 40 per cent of the total commercial energy was consumed in the industrial sector (excluding the power industry). The contribution to this sector from non-commercial energy sources, such as bagasse, rice husk and solar energy, is negligible.

Energy Use Pattern in India's Manufacturing Industry. In 1985-86, about 500 trillion kilocalories of commercial energy was consumed by industry as purchased fuels and electricity. Coal accounted for 64 per cent and, oil 17 per cent, natural gas 6 per cent and electricity 13 per cent of the total energy used in industry. Table 4 presents the the break-up of energy consumption in the industrial sector for 1985-86.

In the case of coal, the industrial sector consumed about 46.3 per cent of the total coal consumed in India. For oil the corresponding figure is 19.9 per cent, for gas 60 per cent and for electricity approximately 56 per cent. This data is given in Table 5.

2/ Power industry's energy consumption was approximately 27 per cent of the total commercial energy consumption in 1985-86.

Table 3

Trends in Electricity Consumption in Different Economic Sectors

Year	Industries		Residential & Commercial		Agriculture		Others		Total	
	MkWh	% share	MkWh	% share	MkWh	% share	MkWh	% share	MkWh	% shar
1950	3998	72.02	833	15.0	162	2.92	558	10.05	5551	100
1960-61	12455	74.53	2340	14.0	833	4.98	1083	6.48	16711	100
1970-71	34291	70.8	6412	13.24	4470	9.23	3263	6.73	48436	100
1984-85	73455	58.95	22001	17.66	21194	17.01	7947	6.38	124597	100

Table 4

Break-up of Energy Consumption in Industrial Sector, 1985/86 (P)

Energy Form	Quantity	Energy, 10^{12} kcal	% of total
Coal	70.5 Mt	317	64.0
Oil	8,635 Thousand tonnes*	86	17.4
Gas	2,970 M cu.m (P)	27 (P)	5.5
Electricity (purchased)	75,310 MkWh (P)	65 (P)	13.1
Total		495	100.0

P - Provisional

* Excludes naphtha used as feedstock.

Table 5

Energy Consumption in Industrial Sector, 1985/86 (P)

Energy Form	Unit	Nation	Manufacturing Industry	%
Coal	Mt	152.43	70.5	46.3
Oil	'000 t	43,305 (P)	8,635*	19.9
Gas	M cu.m	4,950	2,970 (P)	60.0**
Electricity	MkWh	134,480	75,310 (P)	56.0**

P - Provisional

* Excludes naphtha used as feedstock

** Percentage of the national consumption assumed based on previous years' consumption trends

Energy Conservation. The Inter-Ministerial Working Group on Utilization and Conservation of Energy had estimated in 1983 that the total potential for energy conservation in the industrial sector is approximately 25 per cent of the total energy consumption. This group had reported that with an investment of Rs. 36,000 million in energy conservation measures, an annual saving of Rs. 19,250 million could be realized in the industrial sector. In comparison, a total investment of Rs. 57,800 million would be needed in the energy supply sector to create an equivalent capacity. The energy consumption in industry has been increasing at an annual rate of roughly 4 per cent (in physical units). Therefore, for 1987-88, if one computes similar figures as above, taking into account energy price and other cost escalations, one would find the numbers much higher. It is clear from the above figures that the investment required to create additional energy supply is much higher than that required for energy conservation measures.

Table 6 illustrates the potential for energy conservation in four major energy-intensive industries in India, by comparing specific energy consumption in India with that of a few developed countries.

Table 6

Specific Energy Consumption in Selected Industries in India as Compared with those of Developed Countries

(million kcal/tonne)

	Steel	Cement	Pulp & Paper	Fertilizer
India	9.50	2.00	11.13	11.25
Italy	4.03	0.89	-	9.92
Japan	4.18	1.20	-	-
Sweeden	5.02	1.4	7.56	-
UK	6.07	1.3	7.62	12.23
USA	6.06	0.95	9.70	11.32
West Germany	5.21	0.82	-	-

As in many other developing countries, in India the potential for energy conservation remains high and it is virtually untapped. The industrial sector, being the more organized sector, is the prime candidate for implementation of energy conservation measures.

The case for energy conservation does not require to be overemphasized. It is a known fact that conservation measures are cost-effective, require investments which are much smaller than what would be needed to produce additional energy equivalent to the energy they save, and above all, have very short gestation periods, unlike energy supply projects which take years to plan and implement. Therefore, energy conservation programmes, deserve to be given (while planning our future strategy), at least as much importance as programmes for augmentation of energy supplies.

CONCLUSION

If one looks at the demand projections made by the Advisory Board on Energy for the year 2004-05, one would realize that the country is faced with the prospect of a most serious energy crisis and therefore of economic stagnation in the near future. The situation obviously calls for the most energetic action on both supply and demand fronts.

On the supply side, improvement in PLF, and reduction in transmission and distribution losses will go a long way in reducing the requirements of additional capacity for power. Improvements in the current levels of productivity of coal, setting up of coal washeries and efficient movement of coal are also necessary. As regards oil, exploration must be stepped up. Better utilization of natural gas and exploring possibilities of additional uses of natural gas is vital to the Indian economy.

On the demand side, there is no option other than to ensure that all forms of energy are used with the maximum possible efficiency and that the highest standards of conservation are achieved in the shortest possible time.

It should be mentioned that efforts are under way to create greater awareness in energy conservation, to conduct more training programmes in energy demand management, to perform energy audits on a wider scale, to set norms for energy consumption in industry, etc. However, to realize the energy conservation potential in industry, an integrated approach is necessary. To achieve the desired results in this area, a sustained and planned national campaign for energy conservation is essential.

Acknowledgement

Input from the Tata Energy Pesearch Institute on various energy supply and demand data is acknowledged.

ENTERPRISE LEVEL PROGRAMME
FOR PROMOTING RATIONAL USE OF ENERGY

Reading Material for
Training Programme on Energy Conservation
at Bharat Pumps and Compressors Limited
Naini, Allahabad
January 7-8, 1988

VIRENDRA S. KOTHARI
Tata Energy Research Institute
7, Jor Bagh, New Delhi 110 003

WHY ENERGY MANAGEMENT ?

Energy is a vital input to industrial production. The high levels of energy use in Indian Industry compared to other countries, the increasing problems of energy unavailability, and the rising costs of energy point to the use of energy management at the enterprise level as a sound strategy to reduce costs, improve productivity, and increase profitability. In most cases, energy management can lead to 15-20 % savings in the short and medium term with low requirements of capital investments. These savings can generally be achieved irrespective of the size of the organisation and the manufacturing activity it is engaged in.

This paper describes the approach and considerations that go into developing a programme for rational use of energy at the enterprise level. Broadly, this comprises four phases:

- Establishing a management structure for energy management
- Initiating energy management activities
- Managing the programme once it is underway
- Maintaining energy management activities permanently

ORGANISING ENERGY MANAGEMENT

The most essential requirement for a successful energy management programme is the commitment and dedication of top management. They must be totally convinced of the need, necessity, and benefits of energy management. They must be willing to provide the resources, both personnel and capital. They must visibly demonstrate and communicate their commitment to the employees of the enterprise.

Once a corporate decision has been made to start an energy management programme, a special management structure within the company's organisational framework needs to be created in view of the special role of energy as a common input across different divisions, departments and sections.

The first step in this process is the appointment of a corporate energy manager. The person appointed to this post should be a senior manager and should report directly to top management. This also serves to demonstrate to all employees the importance attached to energy management. This position requires full time attention except in small companies. The person appointed as corporate energy manager must be knowledgeable about all aspects of the company's operations and energy usage, committed to energy management, influential and assertive.

The energy management structure will depend on the size of the enterprise, its functional organization, and its manufacturing activities. In large enterprises having several plants, an energy manager reporting to the plant manager and to the corporate energy manager would be responsible for the energy management programme in each plant. Responsibilities at divisional levels would rest with energy management coordinators in each division. At the departmental level, the most effective practice has been to make a supervisor responsible for the energy management programme. The structure in medium size companies could be similar to that for a single plant in large companies. In small companies, it may not be necessary to have an energy manager at all. This role could be assigned to any of the managers responsible for engineering, maintenance or production, or to a senior staff member.

A useful practice is for the energy managers and coordinators to be assisted by committees consisting of representatives of various functional areas such as engineering, maintenance, utilities, production, shift organisation etc. These committees would assist in developing programmes and formulating plans, serve as a channel for communication back to personnel in their functional area, and also serve as a forum for review and generation of ideas. Membership in these committees could be rotated on a planned basis to involve a greater number of people and get more ideas.

INITIATING ENERGY MANAGEMENT

With the appointment of a corporate energy manager and the establishment of an appropriate energy management structure, the process of planning and initiating energy management activities can be undertaken. This comprises of three major steps :

- Setting overall energy management policies
- Conducting plant energy studies
- Formulating a plan of action

Step 1 : Setting Overall Energy Management Policies

The first step is setting of overall policies relating to objectives, goals, methods, resources etc. Some of the questions that should be addressed in this context are:

- What are the objectives of the energy management programme ? These could be minimisation of energy wastage through better housekeeping, improvement of efficiency of energy consuming equipment, substitution of expensive or scarce fuels, incorporation of better operating and maintenance practices, training of operators for energy-efficient operation etc.

- What are the goals ? These can be expressed in terms of expected reduction in energy consumption or energy costs over a specified time period.

- What are the possible methods to achieve the desired objectives and goals ? These could include plant energy studies, incorporation of technological developments, equipment modification or replacement, streamlining of operating procedures etc.

- What resources - personnel and capital - are to be committed ?

- How will the achievement of objectives and goals be monitored ?

Clearly, these questions cannot be answered without some knowledge and understanding of the plant's energy consumption patterns and trends. This requires atleast an analysis of historical data on the quantity and costs of various forms of energy used within the plant, and the specific consumptions or energy intensities, i.e. the ratio of energy inputs to production outputs. These analyses are very useful in highlighting major trends in energy consumption at the overall corporate or plant level.

It would appear that some of these questions would be better addressed as the energy management programme progresses. This is indeed so. Nevertheless, it is very important and in fact essential at the very outset to define overall policies, even in somewhat preliminary fashion, which would serve as the basis for an initial commitment. As the programme proceeds, these policies should be reviewed and revised, if necessary.

Step 2 : Conducting Plant Energy Studies

To save energy, it is necessary to know where, how and how much energy is being consumed. The objective of plant energy studies, also referred to as energy audits, is to characterise and quantify the use of energy within the plant at various levels - in departments, sections, major processes, and major equipment. The plant energy study provides a comprehensive and detailed picture not only of the type and quantity of energy being used but also how efficiently it is being utilised, the mechanisms by which energy is being lost, and the amounts of energy being thus lost.

Plant energy studies can be carried out in two sequential phases - a preliminary study and a detailed study.

The preliminary plant energy study or preliminary energy audit is essentially, as the name implies, a preliminary data collection and analysis effort. Readily available data on the plant's energy systems and energy-using processes or equipment are obtained and studied. The operation and condition of equipment are observed by going around the plant and discussing aspects of these with plant personnel. The data and observations are then blended with personal experience to develop recommendations for immediate short term measures, and to provide quick and rough estimates of savings that are possible and achievable. A preliminary study usually identifies and assesses obvious areas for energy savings such as steam leaks, compressed air leaks, poor or missing insulation, condensate recovery, idling equipment, deterioration and deficiencies in combustion and heat transfer equipment etc., and serves as a basis for the detailed plant energy study.

The detailed plant energy study is a comprehensive analysis and evaluation of all aspects of energy generation, distribution and utilisation within the plant. The analysis is based on consistent and detailed accounting of all energy inputs into a system and all energy outputs from a system which results in the development of energy and mass balances. At the plant level, the analysis requires time series data on a daily, monthly, or yearly basis on the quantities of all forms of primary energy flowing into the plant, e.g. coal, fuel oil, electricity etc., and production figures of major products, by-products and waste products. At the department or section level, information is required on the quantity of energy forms and utilities consumed, and the production figures of intermediate products. At the equipment level, in addition to the quantities of energy forms and material products, process parameters such as temperature, pressure, flow etc. are also required.

Data generation and collection is an essential and critical element of a detailed plant energy study. Difficulties in meeting data requirements generally arise due to unavailability of plant operating data, inadequate instrumentation, poor accessibility of equipment, unavailability of plant design data, and unavailability of historical records. The acquisition of actual operating data through existing or new permanently installed instruments or portable test instruments cannot be overemphasised in this context.

Measurements are critical in any serious effort to conserve energy. Apart from helping to quantify energy consumption, measurements also provide a means to monitor equipment performance and check equipment condition. Examples of measurements and instrument types are :

- Flow/Velocity : Orifice plate, Pitot tube, Venturi tube, Turbine meter, Vortex shedding flowmeter, Ultrasonic flowmeter
- Temperature : Thermometers - Bimetallic, Resistance etc., Thermocouple, Radiation pyrometer
- Pressure : Bourdon gauge, Diaphragm gauge, Manometers
- Stack Gas Analysis : Orsat apparatus, Oxygen analysers, Carbon dioxide analysers, Carbon monoxide analysers
- Heat Flow : Thermography equipment
- Electrical : Multimeter, Ammeter, Wattmeter, Power factor meter, Light meter
- Steam Trap Testing : Stethoscope, Ultrasonic detector

Analysis and evaluation of data leads to identification of various measures that would save energy. These measures are then evaluated with regard to their technical and economic feasibility resulting in recommendations for further action.

An energy audit is not an end in itself. It does not save energy; it merely indicates areas with the greatest potential for energy (and monetary) savings, and therefore, areas where further action needs to be concentrated. It also provides a starting point or baseline from which progress on energy conservation can be measured.

The duration of these studies depends on plant size and complexity. The preliminary energy study can be carried out in a few days and can usually be completed in a single day. The detailed study would require anywhere from one man-week to several man-years of effort. Plant energy studies can be carried out in-house if adequate resources and expertise exist for doing so. Alternatively, or additionally, external assistance may be sought from energy consultants, equipment vendors, and engineering and design firms. In either case, intense interaction between plant personnel and the study team is essential for a proper understanding and a meaningful analysis of the plant's energy options. Too often, the plant energy study is considered to be the consultant's 'problem', resulting in minimal inputs and involvement from plant personnel. This altitude is counter-productive and self defeating. Without the active participation of all levels, savings in energy use cannot be expected and accomplished.

Step 3 : Formulating a Plan of Action

In most cases, drawing implementation plans can begin even while the plant energy study is underway. This is particularly so for measures emphasising better housekeeping which are usually low capital but manpower intensive options. Once the energy audit is complete, it should be carefully reviewed and a detailed implementation plan devised. At this stage, the overall energy management policies formulated earlier should also be reviewed and suitably amended, if necessary. For example, the energy audit may indicate that the goals set earlier were too low, and an upward revision may be required. Goals should be tough but realistic.

The implementation plan must include specific time schedules for specific projects or categories of projects. Individual responsibilities must also be assigned. Management must exercise due control and authority to ensure that plan implementation is as per schedule. Periodic progress reviews at quarterly or half-yearly intervals should be carried out to assess implementation progress, to ensure that anticipated savings are being realised, to review any energy savings opportunities identified subsequently, and to assess the impact of changes in factors such as energy prices, production levels, production mix etc. on the energy conservation programme.

MANAGING ENERGY MANAGEMENT

Having initiated an energy management programme, proper management is essential to reap the benefits that are expected. Two major elements of this managerial function are motivating employees to participate and contribute, and monitoring of progress.

Motivating People

Employees can be motivated to support and actively participate in an energy management programme through:

- Awareness and Information
- Involvement
- Incentives and Rewards
- Publicity and Promotion

Awareness and Information

In most plants, employees have little or no idea of the amounts of energy being consumed within their plant, their section and even the equipment being operated by them. In such a situation, energy conservation obviously carries no meaning. Employees can be stimulated to support energy management by making them aware of the amounts of energy they are using, the associated costs, the many ways to save energy the dependence of energy consumption on other factors such as production rate, and the importance of energy conservation for the company's profitability and the nation's growth. The information can be provided in the form of comparisons of historical trends, current values and goals for overall energy use, energy intensity etc. in both physical and monetary terms; energy conservation checklists for each manufacturing operation outlining simple and routine housekeeping measures to save energy, audio-visual presentations, and other general literature.

Information must be presented in a manner which facilitates comprehension. If the information is too technical, too much, too sketchy or too dull, it is likely to be ignored or not understood. Terms that employees can relate to in everyday life should be used. For example, a sign saying 'Stop steam leaks' will not be as effective as a sign saying 'A quarter inch diameter steam leak costs Rs. 30,000 per month'.

Training is also an important means of both informing and involving people at all levels in an energy management programme. For operating personnel, training is required in energy efficient operation of equipment and the practicalities of energy saving. This could be integrated into the organisation's other training programmes. Upper level management also need to be informed of the overall energy situation, energy costs in relation to other costs, the energy management programme - its goals, achievements, technical, economic and behavioural aspects etc.

Involvement

Motivation is based on involvement. Commitment and a sense of personal accountability can be generated only through total involvement of plant personnel at all stages from initiation to implementation of the energy management programme.

Involvement must begin with the top management. As mentioned earlier, top management must be fully committed to the energy management programme and must visibly demonstrate their commitment and involvement in every manner possible and at every available opportunity. Top management must originate the programme, generate momentum and then maintain momentum. Adequate personnel and financial resources must be provided and responsibilities delegated to implement activities and projects to achieve the predetermined energy conservation goals. Progress should be monitored and goals reviewed and revised in the best interests of the company.

Operators and maintenance staff should be involved actively as they are ultimately responsible for execution of activities in the programme. Also, they are often in a better position to recommend areas for savings or improvements. The most effective way of involving them is by simply going out and talking to them regarding goals, achievements, problems, and progress or lack of progress. This demonstrates to them that the energy conservation programme is real and also that their role is important in success or failure of the programme. Another means of involvement is through training.

Supervisors and middle level management should be involved by assigning them responsibilities for implementing and monitoring activities and submitting performance reports to top management, and by getting them to interact and communicate with operations and maintenance staff on progress and problems. If possible, energy management activities should be made a part of each supervisor's performance or job standards.

Incentives and Rewards

Another method of motivating people is through incentives and rewards. Monetary rewards could be given to employees for suggestions leading to substantial energy savings, for innovative ideas or solutions, and for outstanding efforts in implementation of energy conservation activities. Wide publicity of effective ideas provides an added incentive in the form of public recognition. Other incentives could be designed to meet the needs and attitudes of plant personnel.

One possible danger with monetary rewards is that it makes people accustomed to receiving extra compensation for an effort that really is part of their job. If rewards are stopped later, there could be a reduction in ideas that could affect original gains.

Publicity and Promotion

Publicity and promotion are essential to make the energy management programme successful. These aid in monitoring employees through the three methods mentioned above. Some suggestions for publicising and promoting an energy management programme are listed below[1/] :

1. One article per month is written in the company or plant paper. Include a personal profile on people performing energy management activities and at least one good energy conservation idea that was implemented.

[1/] Adapted from Williams, M.A., Initiating, Organising and Managing Energy Management Programs, in Turner, W.C. (ed.), Energy Management Handbook, John Wiley, New York, 1982.

2. Articles from the company or plant paper are used to obtain local newspaper interest and coverage.

3. Posters and pamphlets on energy conservation.

4. Decals for hard hats with an energy conservation reference.

5. Operating department note paper with different energy conservation opportunities and ideas printed on the paper.

6. Plant-wide high-visibility vehicles or equipment are used to carry signs publicising energy conservation.

7. Energy conservation performance results for plant and department are posted monthly by the plant energy manager and the unit representative (division or department energy management coordinator).

8. Plant energy manager and unit representatives have face-to-face energy conservation discussions with plant personnel. The opportunity checklist can be used for discussion topics.

9. Unit representative and several unit personnel conduct quarterly on-site reviews, a walk-through of the unit looking for energy-saving opportunities.

10. An agenda item on energy conservation is included at staff meetings.

11. Energy conservation material is provided to first-line supervisors for hourly employee discussion periods at least quarterly.

12. Quarterly meetings are held in the plant for all unit representatives.

13. Annual meetings are held for plant energy managers.

14. An Energy Awareness Day is set aside in the plant twice a year.

15. A company energy logo is developed and adopted.

Monitoring and Reporting

Monitoring of the energy conservation programme is necessary to ensure that it is on schedule and that established goals and objectives are being met. Programme momentum can also be maintained through monitoring. This requires tracking of selected measures of performance.

Selection of the appropriate and relevant measures is essential for proper monitoring. For example, at the plant or department level, energy usage or cost trends could be tracked. However, these are not unique measures by themselves. Energy usage could also vary due to changes in production volume or production mix. Energy costs would also change due to increases in prices. A better factor is the energy intensity, or energy consumption per unit output, although even this is a function of production rate. Another method could be the use of an energy conservation index wherein current energy use is adjusted to compare with energy use in a certain base period.

Starting from the overall company or plant, monitoring should be carried out at the lowest level possible. This allows closer monitoring of progress and deviations, and faster response to overcome problem areas.

Effective monitoring requires that a reporting system be developed and instituted. Report contents and frequency should be tailored to the audience. Reports to top management could be submitted quarterly giving monetary savings, energy savings, capital expenditures and other expenses, and measures of performance such as energy intensity or energy conservation index, all shown against their goals, and a brief description of activities for each plant or department. Reports to plant managers would be more detailed and more frequent, say monthly. Reports should contain more specific and detailed information at lower managerial levels. For a few key areas, such as peak electrical demand, steam venting etc., reporting could be on a hourly, daily, or weekly basis to monitor energy consumption or wastage more closely.

Installation of required instrumentation, acquisition of necessary data, proper maintenance of plant log sheets, and consistent energy accounting are essential for reporting and monitoring. In this context, it is important to reiterate the need for instruments and measurements not only during the energy audit phase but also during subsequent implementation of energy saving schemes.

MAINTAINING ENERGY MANAGEMENT

Energy management is not a one shot affair. Rather, it should be a continuing programme whose focus and strategies may change over time. The overall objectives, however, are invariant.

Results of the energy management programme shoud be reviewed annually to determine whether the objectives and expected savings have been achieved. Based on the review, policies should be reassessed and the plan of action revised. The energy reporting system should become an integral part of existing management information systems. Employee motivation should be sustained. Technological developments should be continuously monitored and evaluated. A frequently neglected aspect is the contribution of a good preventive maintenance programme to effective energy management. Only by sustaining the momemtum and the efforts will energy savings continue to accrue.

SUMMARY

More than ever before, energy management is the need of the hour. It is easy and simple, involving the application of well known principles and techniques. It is also cost effective. Irrespective of the size of a company and its plants, an energy management programme can be initiated in a few months, and savings can be realised almost from the beginning. An energy management programme in any company is a sound investment with returns comparable to the best elsewhere.

ENERGY AUDIT

Reading Material for
Training Programme on Energy Conservation
at Bharat Pumps and Compressors Limited
Naini, Allahabad
January 7-8, 1988

G. SAMBASIVAN
Tata Energy Research Institute
7, Jor Bagh, New Delhi 110 003

ENERGY AUDIT

INTRODUCTION

Need for Energy Audit

Energy audit is a vital link in the entire energy management chain. The Energy Manager/Energy Cell, in proposing courses of action and evaluating their results, requires a detailed information base from which to work.

The information base is produced by energy audit - a vital element in the overall energy management programme.

The overall programme includes other managerial and operational activities and responsibilities. However, the audit process is the most important part of the programme, and is essential to the programme's implementation and success.

Definitions of Energy Audit:

Here are two definitions of energy audit:

- The energy audit serves to identify all the energy streams into a facility and to quantify energy use according to discrete function.
- An energy audit may be considered similar to the monthly closing statement of an accounting system. One series of entries consist of amounts of energy which were consumed during the month in the form of electricity, gas, fuel oil, coal, etc., and the second series lists how the energy was used, i.e., how much in lighting, in air-conditioning, in heating, in process, etc. Energy audit must be carried out accurately enough to identify and quantify the energy and cost savings that are likely to be realized through investments in energy saving measures.

A simpler definition for an energy audit is :
"An energy audit serves the purpose of identifying where a plant facility uses energy and it identifies energy conservation opportunities."

Relevance of the term Audit in an Energy Audit

The term audit signifies an analysis of the input and output parameters to evaluate discrepancies, if any. To that extent, energy audit also aims at identifying, evaluating and analyzing the various forms of energy input and output. But the scope of energy audit does not end here. With the help of this information, potential areas of energy conservation are identified so as to review the specific energy input both in terms of cost as well as absolute quantity. Energy audit also throws pointers where further action may be required for improving the performance of equipment/processes. It, therefore, lays foundation for development of better processes. In an energy audit, the study of systems interaction effect opens up the potential for improvement in other areas such as quality, working conditions, environmental effects, etc. Thus energy audit is not merely an audit but is more of a total systems improvement technique.

Types of Energy Audit

The type of energy audit performed depends on:

- the function and type of facility
- the depth of the audit and its findings
- the potential and magnitude of cost reduction

Recognizing the fact that energy audit is an essential element of the energy management programme and considering cost and time factors, energy audit could be broadly classified as preliminary or walk-through energy audit and detailed energy audit.

Preliminary or Walk-Through Energy Audit

Preliminary Energy Audit (PEA) focuses on major energy supplies and demands, usually accounting for approximately 70 per cent of total energy. It is essentially a preliminary data gathering and analysis effort. It uses only available data and is completed with limited diagnostic instruments or aids. The PEA is conducted in a very short time frame (i.e. a day or a few days), during which the energy auditor relies on his experience to gather all relevant written, oral, or visual information that can lead to a quick diagnosis of the plant energy situation. The PEA focusses on the identification of obvious sources of energy waste. Examples of easily identified waste are missing insulation, steam and compressed air leaks, in-operative instruments and equipment operating unnecessarily. The typical output of a PEA is a set of recommendations on immediate low-cost actions that can be taken up by the immediate departmental head and, usually, a recommendation for a more extensive plant energy analysis, i.e., detailed energy audit.

Detailed Energy Audit

Detailed energy audit goes beyond quantitative estimates of costs and savings. It includes engineering recommendations and well defined projects, and lists priorities. Approximately 95 per cent of all energy is accounted for during the detailed audit.

The detailed energy audit which must always be conducted after a Preliminary Energy Audit, is an instrumented survey followed by a detailed plant energy analysis. Sophisticated instrumentation, including flow meters, psychrometers, flue gas analyzers and infrared scanners, are used to enable the energy auditor to compute energy efficiencies and balances during typical equipment operation. The actual tests performed and the instruments required depend on the type of facility under study and the objective, scope and level of funding of the energy management programme. Thus, an energy audit can take as little as one man-week or as much as several man years in a sophisticated plant, such as petrochemical complex, where expected savings justify such an effort.

After obtaining the test results, the energy auditor checks and validates them using preliminary computation and existing support materials (tables, charts, manuals, computers). Then, he uses the results to build energy balances, first for each major piece of equipment tested and then for the plant as a whole. From such balances, he can determine how efficiently each piece of equipment is actually operating and whether there is room for improvement. Next, he analyses the data, concentrating on identifying costs and benefits of selected options (actions, investments) for each opportunity. In some cases, the energy auditor will be unable to recommend a specific investment because of its magnitude or the associated risk. In such a case, the auditor will recommend specific feasibility studies (e.g. boiler replacement, furnace modification, steam system replacement, etc.). The energy audit stops at this point; its final output is a detailed report presenting the auditor's recommendations, together with their associated costs, benefits, and implementation characteristics (timing, impact on production, etc.)

The comparison of major features of walk-through and Detailed energy audit is given in Table 1.

PROBLEMS ENCOUNTERED IN CONDUCT OF ENERGY AUDIT STUDY

The Energy Audit Studies conducted by the National Productivity Council have revealed that there are several major problems which come in the way of conduct of energy audit studies in industry.

a. Lack of Information

It has been found that many units do not have the basic information system to give even the order of magnitude figures. Figures available are based mostly on some assumed norms which have little bearing on the actual situation at the shop-floor.

b. Energy Consumption Norms

In the case of industries producing only one product, energy consumption per unit of product can be worked out from the figures of total production and total energy consumption. However, this is not possible in the case of industry having a number of products since it may be difficult to separate the energy consumption for the various products being manufactured.

c. Energy Consumption Norms in Industry

It was often observed that the energy requirements of the various items made was difficult to quantify. While the total cost of electricity, fuel and water, for example, were available, the particular efficiency of individual plant items were unknown. Since this data is very much necessary for every audit, a lot of time is taken for collecting and assessing this information.

d. Lack of Instrumentation

In the case of small and medium-scale industries, lack of instrumentation has been recognized as a major deterrent. Even though instruments were installed in the large-scale industry but their proper functioning and reliability was not sure. Instruments used in a majority of our industrial boilers are usually the minimum required as per the statutory laws governing boiler code to allow the safe operation of the boilers. Industrial furnaces are generally not instrumented. As a matter of fact most of the industrial boiler and furnaces are not provided with instruments sufficiently to record the equipment performance which can be used in the energy audit study. This is particularly true of the older type of the shell boiler and furnaces used in the engineering industry for operations such as forging, heat treatment and rolling.

Source : Adapted from "Energy Audit", Background paper at the Workshop on Empanelling Energy Auditors, September 1987, National Productivity Council, New Delhi.

Table 1

Comparison of Major Features of Preliminary and Detailed Energy Audits

Sl.No.	Description	Preliminary or Walk-Through Energy Audit	Detailed Energy Audit
1.	OBJECTIVE	Inspect major energy areas and opportunities	Define, quantify, engineer and assign priorities to virtually all opportunities
		Account for 70 per cent of energy used	Account for 95 per cent of all energy used
		Be usable as follow-up on previous audit	Formulate new long-range plans
2.	SCOPE	Group projects as ready for immediate dept. head decision or in need of further definition	Group projects as no cost, expense or capital
		Highlight overall energy costs and economic incentives	Perform detailed engineering calculations
		Include general recommendations on status of employer and employee and employee involvement	Determine energy consumption and cost by utility, area and product
			Set up and initiate, employee involvement plan
			Institute no-cost and some expense recommendation
3.	AUDIT TEAM	Three auditors (Two in-house, including the plant engineer or maintenance, supervisor, and possibly one consultant)	Four auditors (Two in-house, including the plant engineer, and two consultants)
		One report writer	One report writer
4.	DURATION	A day or few days	Four to sixteen weeks
		One week for final report	Quarterly audit status report
			Detailed engineering report with full technical and economic analyses
5.	FREQUENCY	Every 6 to 12 months	Every 3 years

Contd..

Table 1 (contd.)

Comparison of Major Features of Preliminary and Detailed Energy Audits

Sl.No.	Description	Preliminary or Walk-Through Energy Audit	Detailed Energy Audit
6.	PREPARATION		
	a) Pre-Audit Plan	Staffing	Advance notices to department heads
		Check lists	Adequate office and secretarial support
			Advance daily schedules
	b) Facility Familiarization	No Pre-audit visit	Two or more Pre-audit visits
	c) Audit Kit	Clip board	Short audit kit, infrared camera, Portable flow and temperature recording instruments
			kWh meter
	d) Flow-Diagrams	Overall product flow and production rates by areas	Up-to-date schematics
			All schematics in same format
	e) Energy Balance	Overall plant	Overall plant by area and products
		Utilities building	Individual utilities
	f) Consumption and cost data	Annual Energy Bill	All data required for detailed analysis of purchased energy and distributed energy
		Purchased fuels and power profile	
		Data to verify electric power rate schedule	Familiarity with future energy needs and utility contracts

Contd..

Table 1 (contd.)

Comparison of Major Features of Preliminary and Detailed Energy Audits

Sl.No.	Description	Preliminary or Walk-Through Energy Audit	Detailed Energy Audit
7.	SCHEDULE	Brief opening meeting	Opening meetings
	a) General	Closing meeting not necessary	Weekly status meetings
			Monthly review meetings
			Morning inspections
			Afternoon summary sessions
	b) Specific	Hourly, by function area	Daily, by area
			Contacts identified
			Weekly feed back to dept, or area supervisors
8.	AUDIT REPORT		
	a) Contents	Summary, including overall economics	Engineering recommendations
		General findings	Detailed Economic analysis on major items
		Economic incentives	
		Recommendation list including specific findings, energy management, programme, employee involvement	Recommendation on short, mediu and long range needs for energy management programme
		Discussion, conclusion, comments	Emphasis on metering individual uses
		Limited appendix	
	b) Due Date	Within 1 week of last audit day	Within 3 months of last audit day

Contd..

Table 1 (contd.)

Comparison of Major Features of Preliminary and Detailed Energy Audits

No.	Description	Preliminary or Walk-Through Energy Audit	Detailed Energy Audit
	APPLICATION OF RESULTS	Clearly define and communicate functional responsibilities	Assign an engineer to each project recommendation
		Put recommendations into a schedule	Define project schedules fully
		Institute tuning, operational and maintenance items and outline approach to medium to long-range recommendations	Define and communicate capital needs for next 5 years
			Establish a separate energy budget for recognized and approved projects
		Establish a follow-up agreement including a formal reporting system	Establish a return visit frequency with an interim reporting system
		Decide when and if a Preliminary/Detailed audit will be needed	Contract out large project that are beyond plant capabilities

FUEL ECONOMY IN FURNACES

Reading Material for
Training Programme on Energy Conservation
at Bharat Pumps and Compressors Limited
Naini, Allahabad
January 7-8, 1988

HANAGUDU HARISH
Tata Energy Research Institute
7, Jor Bagh, New Delhi 110 003

FUEL ECONOMY IN FURNACES

Introduction

Thermal efficiencies of industrial fuel fired furnaces generally range between 10 per cent and 40 per cent. These efficiencies vary depending upon the temperature requirements, loading and operating practices. Only continuous furnaces reach higher efficiency figures.

Detailed investigations of furnaces have shown that many furnaces operate well below optimum overall efficiency, and substantial fuel savings can be achieved by the simple application of basic principles.

In addition, improved fuel utilization results in increased productivity, lower rejection rates, lower maintenance costs and a better working environment.

The major factors that affect efficiency and operating performance of furnaces are discussed below:

Fuels

The choice of the right fuel is of greatest importance for every industrial process as it can have a vital effect on:

- Production costs
- Work quality
- Maintenance costs
- Productivity
- Working environment

The basis of fuel management is measurement, measurement is necessary because it involves the establishment of targets, monitoring of performance, fuel conditioning etc. It demands also, a willingness to alter traditional methods to take advantage of potential fuel savings.

Gaseous Fuels

Gaseous fuels are perhaps the most suitable of all fuels for application to heat treatment furnaces by virtue of their consistency and ease of control. It can be accurately controlled to give the rate of heat liberation required with the desired furnace temperature.

The use of gaseous fuels often result in reduced maintenance costs, extended refractory life and increased furnace availability.

Liquid Fuels

Liquid fuels have many of the advantages associated with gaseous fuels, however, smokeless combustion of liquid fuels cannot be achieved without an excess of air, and this makes it difficult to obtain the reducing atmosphere, sometimes required in practice.

For high temperatures, where heat transfer is mainly by radiation, flame luminosity and emissivity associated with liquid fuels, have several advantages.

Design Parameters

Although no fixed rule applies, important factors that need careful consideration include:

- Type size and shape of material to be processed
- Temperature requirement of heating cycle
- Size and configuration of furnace chambers
- Furnace throughput or melting rate
- Batch or continuous operation
- Furnace atmosphere requirement

It is of primary importance, that designed capacity of furnace is closely related to the required output. One of the main causes of furnaces operating inefficiently, lies in, incompletely filled furnaces.

Heat storage capacity and structure

Heat losses

Where furnaces operate intermittently it is necessary, if high thermal efficiency is to be achieved, to use materials, and furnace wall thicknesses properly related to the hours of use, required temperature, operating cycle and hearth loading rates. Too heavy a construction and over-insulation increases heat storage capacity and is wasteful of fuel. The amount of insulation to be used, is a simple matter of economics. Insulating materials owe their lower conductivity to the pores, while their thermal inertia depends on the weight per unit volume of its solid and its specific heat.

Insulating bricks

There are in general, three types of insulating bricks:

- Products made from diatomaceous earth – used behind a dense refractory base, where the furnace is operating continuously under severe condition of atmosphere or high temperature
- Products derived from vermiculite
- Refractory (fire clay or silica) based product – known as insulating refractories and are used as inner lining in furnaces.

Ceramic Fibres

Ceramic fibre is made from high purity alumina-silica clay. It is an ideal hot face lining for small furnaces operating at temperatures up to 1260^{o}C. In its blanket form it is easy and quick to install. Due to a very low thermal conductivity figure which is 35 per cent better than insulating firebrick and also as it is one-sixth of the weight, heat storage and losses are substantially reduced. Additional advantage is that heating-up and cooling times can be reduced by 30 per cent.

Savings in heat input is significant, but it should also be borne in mind that as a production unit, the furnace with the lower thermal capacity will reach temperature much quicker than one with a heavier construction.

When furnace operation is continuous the thermal capacity of the brickwork is not so important and the main objective should be to minimise heat losses from the structure by an adequate insulating backing.

Heat Losses

In furnaces and kilns, heat losses from furnace walls, affect the fuel economy substantially. The extent of wall losses will depend on:

- emissivity of walls
- conductivity of refractories
- wall thickness
- operation of furnace, continuous or intermittent

Figure 1 shows that the coefficient of heat dissipation for rough vertical plane surfaces is higher than vertical aluminium painted walls. The emissivity of walls coated with aluminium paint is also lower than that of bricks.

Heat losses can be reduced by increasing the wall thickness, or through application of insulating bricks. Outside wall temperature and heat losses for a composite wall of a certain thickness of firebrick and insulation brick is much lower due to the lesser thermal conductivity of insulating brick as compared to a refractory brick. See Figure 2.

Combustion Equipment - Burners

The burner should be an integral part of the furnace design and its characteristics should closely conform to the required heat flow and distribution.

Important factors that need careful consideration include:-

- Capacity and number of burners required
- Type of flame needed
- Burner turn-down ratio
- Furnace atmosphere required, i.e. oxidising/reducing/neutral

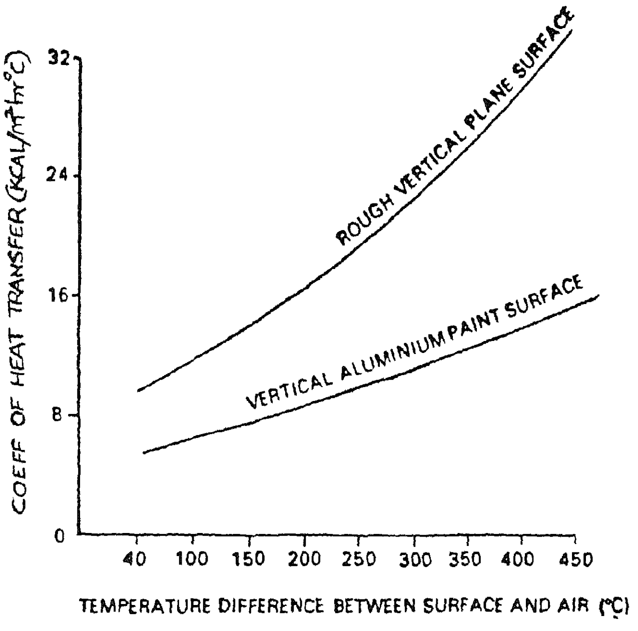

Fig.1—COEFFICIENT OF HEAT TRANSFER FOR DIFFERENT CONDITIONS IN STILL AIR AT 40°C

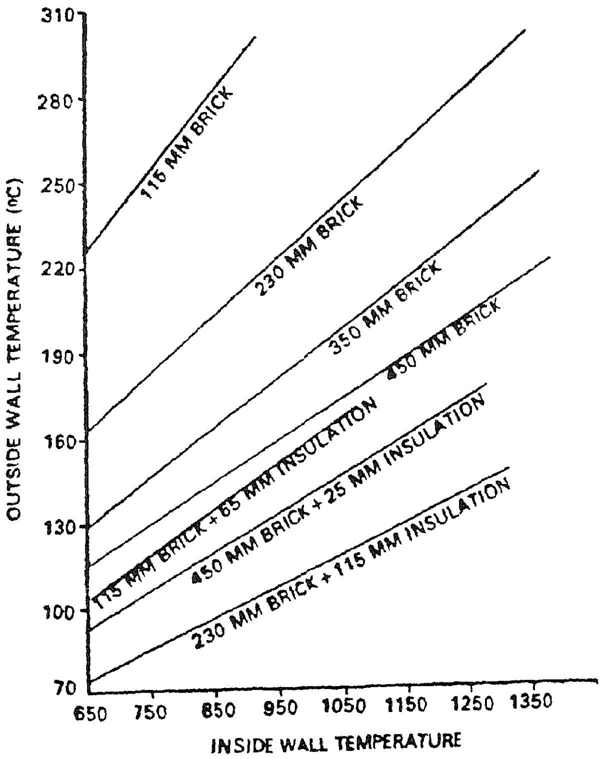

Fig.2 – TEMPERATURE RELATION OF FACES FURNACE WALL

- Ease of ignition and maintenance
- Safety aspects
- Noise emission

The number, size and disposition of the burners or burner ports requires careful attention, if rapid attainment of the required temperature, and uniformity of heating without flame impingement is to be achieved. The size and number of flue off-takes is equally important and they should be located relative to burner positions to give a satisfactory hot gas flow pattern and to ensure optimum travel of the gases before their final discharge to atmosphere. Ideally all parts of the work chamber should be filled with moving products of combustion.

The present trend, is towards the use of packaged and high velocity burners.

A packaged burner includes all required ancillaries as an integral system and is generally manufactured in its entirety at the factory.

High velocity burners use a refractory tunnel of sufficient size, to allow combustion to be completed within the tunnel. The products of combustion are then discharged at high velocity from the exit. High velocity firing promotes turbulence and high recirculation rates in the furnace chamber. In consequence, heat transfer rate is greatly improved and better temperature uniformity is obtained. The use of high velocity burners generally enables the number of burners to be reduced.

Recuperative burners have been designed and developed recently. In a single unit, this incorporates a high velocity burner, flue and recuperator. Combustion air is preheated in the integral recuperator by waste gas, and air temperatures of up to 600^{0}C are possible.

A number of field trials have been undertaken with recuperative burners on conventional furnaces in U.K, and results have shown fuel savings in the order of 30-50 per cent; there appears to be tremendous potential for the future application of this type of burner.

Furnace Operation and Control

The maximum heat input should be carefully related to the temperature and heating rate required and design limitations of the furnace particularly with regard to combustion space volume and capacity of exhaust system.

Excessive fuel input can result in incomplete combustion with high flue gas loss and wastage of fuel. In addition, overfiring can lead to excessive wear of refractories with possible damage to stock.

To achieve optimum combustion efficiency and satisfactory air/fuel ratio, it is essential to burn the fuel with the minimum amount of excess air.

Accurate maintenance of the correct air to fuel ratio is probably the most important single factor in contributing to good operating efficiency. As far as is practicable the optimum CO_2 % should be maintained in the furnace gases, at all rates of fuel input.

Excess air can also have harmful effects on the quality of product, i.e., high free oxygen levels can lead to excessive metal loss and surface damage to stock.

Insufficient combustion air results in fuel waste and a reducing furnace atmosphere is produced, i.e., oxygen free. This can be very deleterious on certain metals, e.g., hydrogen pick up in aluminium melting/holding, or the surface defects on titanium.

Regular check of CO_2 content in waste gases should be made to ensure that optimum combustion conditions are being maintained, and it should never be assumed that once a furnace has been set up correctly, no further attention is needed.

When checking flue gas analysis it is important that the sampling position chosen is one that will give a truly representative figure of combustion conditions as a whole.

Controls

Temperature-Time

Manual control by visual observation can vary widely according to operator's interpretation and this inevitably leads to increased fuel consumption with possible product damage by over or under-heating and excessive oxidation.

Where heating or cooling rates are important an automatic temperature/ programme controller can be used to control the furnace to a predetermined time/temperature schedule. Thus, once the load has been charged into the furnace, heating up, soaking and cooling is automatically controlled. Finally, automatic control of temperature will always give substantial benefits.

Furnace Draught

For good practice, pressure in the furnace working chamber must be slightly in excess of atmospheric, i.e. about (0.02 inch w.g., at all rates of heating.

Negative pressure conditions permit the inleakage of cold air through doors and other openings. This cools the furnace, creates cold spots, increases waste gas losses and drastically affects furnace atmosphere conditions, again often resulting in excessive oxidation of the charge. Figure 3 shows the effect of air infiltration on furnace draught.

Excessive pressure on the other hand may retard combustion development and increase losses by flame and hot gas emission through furnace openings.

The provision of an automatic furnace pressure controller is nearly always a worthwhile investment for not only can fuel economies of around 10 per cent often be achieved by maintaining correct pressure conditions but in addition temperature uniformity and furnace atmosphere conditions will be better resulting in quicker heating up times and improved product quality.

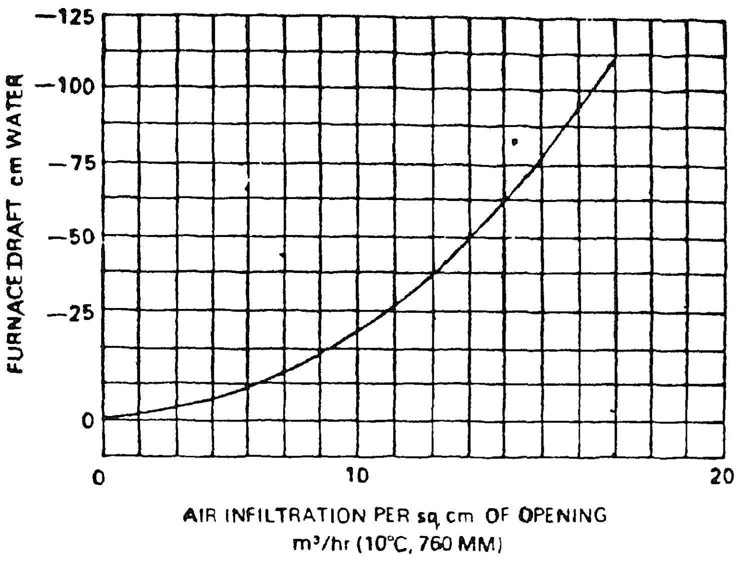

Fig. 3 — EFFECT OF NEGATIVE PRESSURES ON AIR INFILTRATION

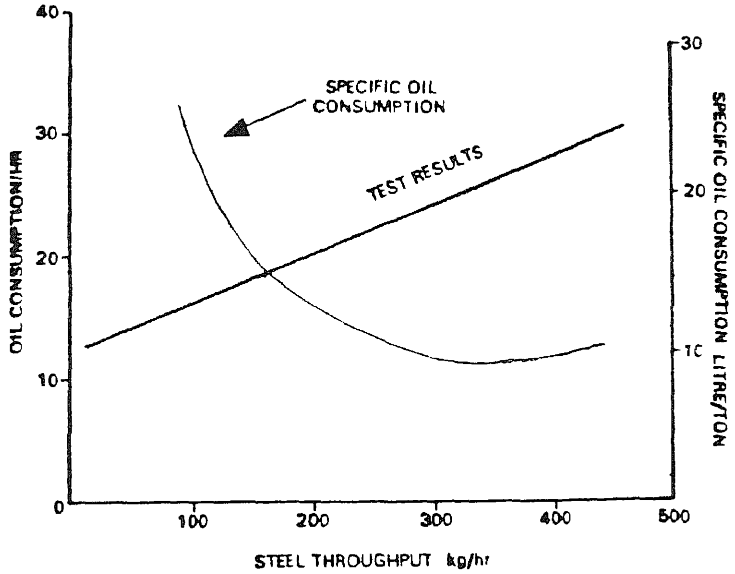

Fig.4 (SLOT REHEATING FURNACE 1 35 m² HEARTH AREA TEMPERATURE 1300°C)

- **Instrumentation**

Adequate instrumentation is an essential aid for the maintenance of optimum furnace efficiency and performance and even more important in the majority of cases, to ensure process requirements are fully met.

Instruments are used to:

- Control temperature/time cycle
- Ensure correct air/fuel ratio is maintained at all rates of heat input
- Obtain required furnace atmosphere
- Ensure fuel is used economically
- Measure and/or record fuel input rate.

One of the best checks on the working of a furnace is to determine and record at regular intervals the amount of fuel used/unit of output. This necessitates, the installation of flow meters. This is usually a wise investment. Comparison of any given week's performance with that of preceding weeks, is a valuable check of furnace efficiency. Any falling off in performance, should be investigated and the aim should be to continuously improve on past records.

Full instrumentation is initially expensive, but experience has shown that a substantial return is obtained in fuel economy, consistent production with minimum rejects, and reduced furnace maintenance costs. Instrumentation can of course, be further developed to incorporate automatic controllers which reduce the work of the operator and can make adjustments much more frequently than any operator could hope to do.

- **Optimum Loading**

One of the most vital factors affecting efficiency is loading. There is a particular loading at which the furnace will operate at maximum thermal efficiency. If the furnace is underloaded, a smaller fraction of the total available heat in the working chamber will be taken up by the load, and therefore efficiency will be low.

The best method of loading is generally obtained by trial - noting the weight of material put in at each charge, the time it takes to reach temperature and the amount of fuel used. Every endeavour should be made to load a furnace at the rate associated with optimum efficiency although it must be realised that limitations to achieving this are sometimes imposed by work availability or other factors beyond control. Figure 4, indicates the effect of increased loading rates on specific fuel consumption. This is for a reheating furnace for drop forgings

Waste Heat Recovery

The major loss of heat from fuel fired furnaces, is that which is carried away as sensible heat in the waste gases. With furnace temperatures varying from say 800° to 1400°C, this loss ranges from 40 per cent to 70 per cent of the heat input.

By recovering and utilising some of this waste heat, overall efficiency can be greatly improved and substantial fuel savings achieved.

Waste heat can be recovered by:-

- Preheating combustion air through recuperators or regenerators.
- Preheating the load before it enters the working chamber by outgoing waste gases - load recuperation.
- External use, for steam raising, space heating, water heating or other low temperature processes.

Combustion Air Preheat

The most effective method of recovering some of the waste heat leaving the furnace is to preheat the combustion air. This method enbales the waste heat to be used at all times the furnace is in operation.

There are two different types of heat exchangers:-

- Recuperators
- Regenerators

Regenerators are normally used, only on large high temperature furnaces. Recuperator is a heat exchanger between the waste gases and the gas to be preheated.

It is important when installing a recuperator in the flue system to ensure that draught loss is minimised, otherwise furnace operation and performance may suffer. Table 1 shows possible savings that can be achieved by preheating combustion air.

Table 1

Fuel Oil, 20 per cent Excess Air

Air Preheat	Savings
100 °C	5.5 %
200 °C	11.2 %
300 °C	16.2 %
400 °C	20.5 %
500 °C	24.0 %

Source: Fuel Economy Handbook, MIFES, London.

ELECTRICAL ENERGY CONSERVATION

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SATISH SABHARWAL
Tata Energy Research Institute
7, Jor Bagh, New Delhi 110 003

A. ILLUMINATION

1.0 Introduction

In Industries, electricity consumption for illumination rarely exceeds 5 per cent of total consumption. In India, it has been our experience that, there is very poor illumination in factories. Proper design, selection and maintenance can however lead to some savings. The following points must be considered.

1. Required lighting levels for different work areas.
2. Selection of light sources.
3. Maintenance and control.

The actual values of lighting levels for different work areas is a controversial subject. Care should be taken to provide different levels of illumination for different tasks. Uniformally high levels of lighting throughout the area of an office or a factory is not required. In India, maximum advantage should be taken of the excellent natural lighting available throughout the year.

Different light sources have different efficiencies for converting electricity into lighting energy. Typical values of light output in lumens per watt of electricity consumed are given below. It is advantageous to use a high efficiency source. Fluorescent lamps can be used in place of incandescent bulbs.

LIGHT SOURCE	LUMENS/WATTS
1. Incandescent Lamp	7 - 13
2. Fluorescent Lamp	30 - 66
3. Low Pressure Sodium Lamp	55 - 125
4. High Pressure Sodium Lamp	60 - 103
5. High Pressure Mercury Lamp	22 - 43

Maintenance and control of lighting must be done very carefully. Dust collected over a period of time can reduce light output by 15 to 25 per cent. In many factories, there is only one switch for control of lighting. This leads to wasteful illumination at many work areas.

Lighting should be controlled separatety for different areas of a plant. This will allow lights to be switched off in areas where no work is in progress.

2.0 Energy Saving By New Types of Lamps

In India, high pressure as well as low pressure sodium lamps are now available. High pressure sodium vapour lamps can save lot of energy compared to mercury vapour and flourescent tube lights. Please see Tables - 1,2,3 given below.

Similarly low pressure sodium vapour lamps can replace incandescent lamps of street lights, security lights and similar applications. Table 4 gives a comparison between low pressure sodium, incandescent and mercury vapour lamp.

36 watts tube lights can be used in place of 40 watts tubes. Similarly special small tubes of 9 watts can replace 60 watt incandescent bulbs.

Table 1

	SON 400W	HPL 1000W
1. Lumen Pack 55,000 lumen	47,000	55,000
2. Equivalent lamps required	1.17	1.0
3. Electrical load (W) each (incl. control gear losses)	430	1,050
4. Equivalent total load (W)	503	1,050
5. % load	48	100

Saving with SON 400W lamp : 62 %

Table 2

	SON 250W	HPL 400W	TL 65W
1. Lumen Pack 22,500	25,000	22,500	4,000
2. Equivalent lamps required	0.9	1.0	5.6
3. Electrical load (W) each (incl. control gear losses)	280	430	80
4. Equivalent total load (W)	252	430	448
5. % load	59	100	104

Saving with SON 250W lamp : 41 % compared to HPL 400W lamp.

Saving with SON 250W lamp : 46 % compared to TL 65W lamp.

Table 3

	SON 150W	HPL 250W	TL 65W
1. Lumen Pack 12,500 lumen	15,000	12,500	4,000
2. Equivalent lamps required	0.84	1.0	3.1
3. Electrical total load (W) each (incl. control gear losses)	175	280	80
4. Equivalent total load (W)	147	280	248
5. % load	53	100	89

Saving with SON 150W lamp - 47 % compared to HPL 250W lamp.

Saving with SON 150W lamp - 41 % compared to TL 65W lamp.

Table 4

Conveyor Gallery Lighting In A Fertilizer Plant

System	XRP 50/33W with SOX35W Lamp	NDC 22 with GLS 200W Lamp	NDC 22 with HPL-N 80W Lamp
1. Number of luminaries	900	1332	1157
2. Lamp life (hours)	15000	1000	5000
3. Lumen output (lumen)	4500	3040	3500
4. System watts (W)	51	200	90
5. Total luminaire cost (Rs.)	306000 @Rs.340/ each	15318 @Rs.11.50/ each	113386 @Rs.98/ each
6. Total luminaire cost (Rs.)	720000 @Rs.800/ each	339660 @Rs.255/ each	804115 @Rs.695/ each
7. Total investment (5+6) (Rs.)	1026000	354978	917501
8. Burning hours per year (hours)	8760	8760	8760
9. Number of lamps to be replaced per year	525	11668	2027
10. Lamp replacement/year (Rs.)	178500	134182	198646
11. Energy consumption/ year (kWh)	402084	2333664	912178
12. Annual energy cost @ Rs. 0.70/unit (Rs.)	281459	1633565	638525
13. Annual runnin charges (10+12) (Rs.)	459959	1767747	837171
14. Annual interest @ 18% on (7) (Rs.)	184680	63896	165150
15. Luminaire Depreciation @ 10% (Rs.)	72000	33966	80411
16. Fixed Annual charges (Rs.) (14+15)	256680	97862	245561
17. Total Annual cost (13+16) (Rs.)	716639	1865609	1082732

B. ELECTRIC MOTORS

1.0 Introduction

Three phase squirrel cage induction motors account for 90 per cent or more of motors used in industries. Slip-ring motors, synchronous motors, D.C. Motors are used for special applications. Squirrel cage motors hence account for a very large portion of industrial electricity use. There is considerable scope for saving in electricity by proper selection and application of these motors. We will illustrate these methods by examples from a wide variety in India.

2.0 Selection of Proper Rating

In last few years, we had the opportunity of studying operations of a number of industrial plants from view point of electricity conservation. In many plants, we find that motor ratings are much higher than required by the load. There are quite a few plants however where motor ratings are properly selected.

Disadvantages of selecting a motor with much higher kW rating than required by the load are as follows.

1. Lower efficiency and higher power consumption.
2. Poorer power factor and higher maximum demand.
3. Higher first cost for motor and control gear.
4. Higher installation cost and larger space requirement.

First let us examine the effect of motor load on efficiency, and power factor. Standard industrial motors maintain good efficiency when loaded in the range of 60 per cent to 100 per cent. Efficiency will start dropping below 50 per cent load. The power factor starts droping even more sharply with load thus leading to higher maximum demand and penaleties for poor powr factor. Table 1 and Table 2 give typical values of efficiency and power factor for motors with rating upto 125 kW at full load, 75 per cent load and 50 per cent load. It can be seen from Figure 4 that efficiency starts decreasing sharply below 50 per cent load.

Table 1

Performance Data For 4 Pole, 415 Volts Motors - TEFC

Sr. No.	Rating kW	F.L. Current Amp.	% Efficiency			Power Factor		
			F.L.	3/4L	1/2L	F.L.	3/4L	1/2L
1.	1.1	2.6	79.0	78.0	74.0	0.75	0.65	0.52
2.	1.5	3.5	80.0	78.5	73.5	0.75	0.65	0.52
3.	2.2	4.6	79.5	79.0	76.7	0.84	0.79	0.64
4.	3.0	6.7	81.5	80.5	76.7	0.76	0.67	0.54
5.	3.7	7.9	83.8	82.8	79.8	0.78	0.69	0.67
6.	4.0	8.9	83.0	82.0	79.0	0.75	0.66	0.51
7.	5.5	10.3	85.0	85.0	84.0	0.87	0.81	0.70
8.	7.5	14.8	85.0	85.5	82.0	0.83	0.76	0.63
9.	9.3	18.8	85.0	83.5	79.5	0.81	0.74	0.60
10.	11.0	20.2	88.0	87.0	84.4	0.87	0.80	0.68
11.	15.0	26.7	88.4	87.6	84.7	0.89	0.83	0.72
12.	18.5	32.5	89.5	89.0	87.5	0.89	0.85	0.75
13.	22.0	38.6	89.7	89.6	87.6	0.89	0.84	0.76
14.	26.0	48.0	88.8	88.5	85.7	0.87	0.83	0.68
15.	30.0	53.2	90.5	90.6	89.5	0.87	0.82	0.76
16.	33.5	60.0	90.5	90.3	89.0	0.84	0.81	0.73
17.	37.0	66.5	91.3	91.0	89.5	0.84	0.81	0.73
18.	45.0	80.0	90.9	90.5	88.6	0.87	0.82	0.74
19.	55.0	98.0	92.7	92.5	91.0	0.845	0.805	0.685
20.	75.0	123.5	92.93	92.55	91.2	0.91	0.89	0.86
21.	90.0	154.0	93.50	93.30	92.3	0.87	0.85	0.78
22.	110.0	190.5	92.4	91.75	89.4	0.87	0.85	0.76
23.	125.0	213.0	93.08	92.5	90.8	0.878	0.84	0.786

Table 2

Performance Data For 4 Pole, 415 Volts Motors - TEFC

Sr. No.	Rating kW	F.L. Current Amp.	% Efficiency			Power Factor		
			F.L.	3/4L	1/2L	F.L.	3/4L	1/2L
1.	0.75	2.2	72.0	70.3	65.0	0.66	0.56	0.44
2.	1.1	3.1	71.0	70.0	65.0	0.70	0.60	0.50
3.	1.5	3.7	77.5	76.5	72.5	0.72	0.60	0.48
4.	2.2	4.7	82.0	80.5	78.0	0.79	0.75	0.67
5.	3.7	7.7	83.8	83.3	60.6	0.81	0.75	0.62
6.	5.5	10.9	84.5	84.5	82.0	0.83	0.77	0.66
7.	7.5	15.8	87.0	85.5	82.5	0.76	0.68	0.53
8.	9.3	19.0	87.5	86.5	82.0	0.78	0.70	0.60
9.	11.0	22.4	87.4	87.0	85.0	0.78	0.71	0.57
10.	15.0	29.1	87.5	87.0	85.0	0.82	0.76	0.63
11.	18.5	35.0	89.8	90.0	89.0	0.84	0.78	0.67
12.	22.0	40.5	90.7	91.8	91.5	0.84	0.82	0.74
13.	26.0	49.0	90.0	90.1	89.0	0.82	0.78	0.65
14.	30.0	56.6	89.9	89.7	87.9	0.82	0.78	0.65
15.	33.5	59.6	91.0	90.8	89.5	0.86	0.83	0.76
16.	37.0	65.8	91.0	90.8	89.0	0.86	0.83	0.76
17.	45.0	79.6	91.5	91.2	90.2	0.86	0.82	0.76
18.	55.0	103.0	93.7	93.9	93.4	0.80	0.74	0.67
19.	75.0	131.0	92.5	92.1	91.2	0.86	0.80	0.72
20.	90.0	161.0	92.8	92.6	91.6	0.84	0.80	0.72

Energy And Demand Savings

A load requires 3.7 kW (5HP) power. In place of 3.7 kW motor, a 7.5 kW (10HP) motor is selected. input power, Input kVA and Savings etc are shown in Table 3.

Table 3

Item	3.7 kW Motor 4 pole	7.5 kW Motor 4 pole
Load	3.7 kW	3.7 kW
Efficiency	83.8 %	82 %
Power Factor	0.78	0.63
Input kW	4.415	4.512
Input kVA	5.66	7.16
kWh Consumption per Annum (6000 hours)	26,490	27,072
kWh Saving/Annum	582	-
Running Cost at 1 Re/kWh	Rs. 26,490	Rs. 27,072
Saving in Running Cost	Rs. 592	-
Annual Saving in demand charges at Rs.50/kVA/month	Rs. 900	-

It can be seen from above table that use of 7.5 kW motor in place of 3.7 kW motor will lead to :

1. Higher consumption by 582 kWh/annum.
2. Higher running cost per annum by Rs. 582.
3. Higher demand charges per annum of Rs. 900.

Examples of Motors in Indian Industries

Table 4 shows examples of motors where the motor ratings are properly selected. Table 5 shows examples of motors where the motor ratings are not properly selected. Normally motors running at 66 per cent to 100 per cent of full load can be considered properly selected. Some application do require special considerations to take care of 1) High inertia, 2) High starting torque, 3) Over loads, 4) Severe voltage fluctuations, 5) Repeated starting and braking etc. Similarly for a wide variety of fan and pump drives, variable speed drives should be considered as an alternative.

Table 4

Examples of Properly Rated Motors

Sr. No.	Industry	Application	kW/HP	Rated	Actual
1.	Chemical	Refrigeration Plant Pump	11 kW	21	20
2.	Chemical	Refrigeration Chilling Compressors	45 kW	77	70
3.	Chemical	Air Compressor	37 kW	70	60
4.	Chemical	Blower	22.5 kW	40	40
5.	Chemical	Cooling Tower Pumps	37 kW	70	70
6.	Paper	Vacuum Pumps	75 kW	108	100
7.	Paper	Refiners	56 kW	97	80
8.	Paper	Beaters	75 kW	135	120
9.	Chemical	Boiler-ID Fan	50 HP	60	59
10.	Chemical	Feed Pump	60 HP	72	72
11.	Chemical	Raw Water Pump	100 HP	125	120
12.	Engineering	Conveyor Plant	90 HP	120	110
13.	Engineering	Conveyor Plant	28 HP	35	30
14.	Engineering	Air-Conditioning Plant	160 kW	300	260
15.	Engineering	Blower	25 kW	45.5	42
16.	Textile	Ring Frame	8 HP	12	11.5
17.	Textile	Auto-loom	2.5 kW	4.7	4.2
18.	Textile	A/C Plant Compressor	100 HP	121	110

Table 5

Examples of Improperly Rated Motors

Sr. No.	Industry	Application	kW/HP Rating	Rated Current	Actual Current
1.	Chemical	Blender	30 HP	42	15
2.	Chemical	Blower	100 HP	130	50
3.	Chemical	Grinder	34 HP	42	21
4.	Chemical	Autoclave	45 HP	44.5	22
5.	Engineering	Machine Tool	25 HP	34	12
6.	Engineering	Machine Tool	20 HP	26	10
7.	Engineering	Pump Motor	30 HP	42	12
8.	Chemical	Vacuum Pump	30 kW	54	30
9.	Chemical	I.D. Fan	15 kW	28	15
10.	Chemical	F.D. Fan	15 kW	28	15
11.	Chemical	Cooling Tower Pump	15 kW	26	15
12.	Vegetable Oil	Compressor	37 kW	66	42
13.	Vegetable Oil	Autoclave	15 kW	66	42
14.	Vegetable Oil	Eleacher	11 kW	22	12
15.	Textile	Draw Frame	14.4 HP	21	12
16.	Textile	Doubler	12.5 HP	17	12
17.	Textile	Ring Frame	20 HP	28	13
18.	Textile	Doubling 2	25 HP	31	11

High Efficiency Motors

It is also essential to select a motor with as high efficiency as possible. Between different brands, there can be differences in efficiency and power factor. Please see Table 6.

Table 6

Performance Data of Different 4 Pole - TEFC Motors

Manufacture Name	Rated Output	Efficiency	Power Factor	Rated Current	Product of P.F.& Effi.
A	1.5	0.76	82	3.4	0.623
	2.2	0.79	0.84	4.6	0.663
	3.7	0.85	0.83	7.3	0.705
	7.5	0.87	0.86	13.7	0.748
B	1.5	0.77	0.79	3.45	0.608
	2.2	0.80	0.77	5.0	0.616
	3.7	0.85	0.77	7.9	0.654
	7.5	0.89	0.80	14.7	0.712
C	1.5	0.75	0.75	-	0.562
	2.2	0.77	0.80	-	0.616
	3.7	0.82	0.82	-	0.672
	7.5	0.84	0.81	-	0.68
D	1.5	0.79	0.75	3.5	0.594
	2.2	0.79	0.85	4.5	0.677
	3.7	0.825	0.88	7.1	0.726
	7.5	0.86	0.87	13.8	0.750

Electricity Prices have gone up 3 to 4 times during last 10 years and are likely to rise sharply in future. Running cost of a motor in one year is many times more than the first cost of the motor. In the earlier example given, it can be seen that a 3.7 kW (5 HP) motor is available for Rs. 3500. Running cost of the same motor in one year is Rs. 26490. Most of the leading manufacturers in the world have come out with series of motors with high efficiency. In India, manufactures can deliver those motors with high efficiency. In India, manufacturers can deliver those motors on special request. The high efficiency motors are 30 per cent costilier than standard motors bt the additional cost will normally be recovered in few months time. It must be however remarked again that high efficiency motors should also be selected such that they run near 75 per cent to 100 per cent of their rated load. Table 7 gives comparison of efficiencies of standard motors and high efficiency motors.

Table 7

Sr.	H.P. Rating	Average Efficiency of Standard Motor	Average Efficiency of High Efficiency
1.	1 HP	73	83
2.	2 HP	77	83
3.	3 HP	80	86
4.	5 HP	82	87
5.	10 HP	85	89
6.	15 HP	87	90
7.	25 HP	89	91.5
8.	50 HP	91	93
9.	75 HP	91	93.5
10.	100 HP	92	94
11.	150 HP	92.5	94.5
12.	200 HP	93.5	94.5

Concluding Remarks

1. Careful selection of motors can lead to saving in first cost as well as running cost. For normal industrial applications, motors should be selected to run at 70 per cent to 100 per cent of rated load.

2. Examples given in the paper show that many industries in India are already very careful in proper selection of motors. There are many more industries however where largely oversized motors are used.

3. It is always worthwhile to pay extra price for motor with higher efficiency.

ENERGY CONSERVATION CONCEPTS FOR DIESEL GENERATORS

Reading Material for
Training Programme on Energy Conservation
at Bharat Pumps and Compressors Limited
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HANAGUDU HARISH
Tata Energy Research Institute
7, Jor Bagh, New Delhi 110 003

ENERGY CONSERVATION CONCEPTS FOR DIESEL GENERATORS

Introduction

Electric power shortage is widespread, crippling operations and industrial productivity. Industries are thus forced to install captive Diesel Generator (DG) sets to augment supply and in many instances provide for the units total power requirement. The numbers of captive diesel generator units installed have shown a rapid increase in the recent past, reflecting the deteriorating utility power supply situation.

Almost all of the presently installed DG sets are designed to be operated on distillate fuels viz., HSD/LDO (High Speed Diesel/ Light Diesel Oil). However, a few new sets being installed, will be operating on Heavy Petroleum Stock (HPS) and Heavy Residual Fuel Oil. The DG sets presently operating, consume distillate fuels which is scarce in the country. Moreover, DG sets being critical equipment for the plant operation, are run for long periods. This leads to substantial costs being associated with the operation and maintenance of the DG sets. Hence, it is vital that adequate attention be provided right from inception, on selection, installation, operation and maintenance of these sets. Training should also be provided to the engine-room operators to appreciate the importance of recommended operational practices and proper maintenance of the DG sets.

This note discusses the several issues related to the proper operation and maintenance of DG sets, leading to better performance efficiency, and fuel conservation.

Factors, which affect the operation efficiency and fuel consumption in DG sets are listed below. Details, explaining the importance of each of them is given. Possible methods and techniques, of improving DG set efficiency are also provided. These factors could be classified as :

- Extent of Loading
- Proper Instrumentation
- Lube Oil Conservation
- Fuel Additives
- Waste Heat Recovery
- Maintenance procedures

Extent of Loading

The extent of loading on diesel generators is a very important parameter in determining the efficiency of engines. Almost all diesel engines have low efficiencies at loads below 50 per cent. A DG set may often, not be made to generate to its full rated capacity. If this happens, the fuel consumption per kWh generated, increases. The increase will depend upon (i) The ratio of actual output to rated capacity; and (ii) design and capacity rating of the DG set. Figure 1, illustrates the observations made in a field test, to study the change in fuel consumption of a DG set at different loads. Table 1 gives a comparison between the recommended and actual specific fuel consumption for DG sets of different capacities. The manufacturers' specifications of part load fuel consumption for different DG sets are provided in Table 2. Note the higher fuel consumption, when the sets operate at lower loads.

However, there are instances, where a DG set is unable to be loaded to its full capacity. This could due to:

- **Overheating of the engines**
  It is recommended, that the cooling circuit be maintained well, and water quality be tested to avoid scale deposition.
- **Poor response of governors**
  Due to the inertia and sluggishness of mechanical governors, DG sets are unable to respond to load changes. It is essential, that the governor mechanism is maintained well.

Proper Instrumentation

Many operators, experience the problem of not being able to detect higher fuel consumption or changes in parameters, due to faulty or improper instrumentation. It is hence, absolutely essential to provide individual flow meters and other indicating instruments to detect the problem early, and rectify in time. Several plants, do not maintain accurate records of HSD consumption in the DG sets. Only data relating to HSD purchased is available. No Fuel Management programme, can take-off, unless the basis of measurement is sound.

Fig 1 Variable load Characteristics of Diesel Gen. Sets

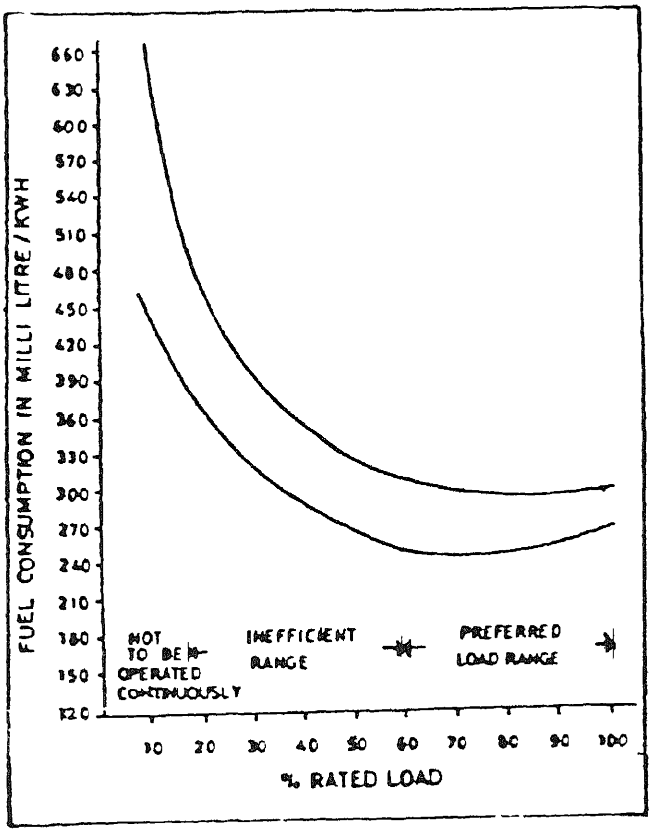

Table 1

Specific Fuel Consumption of HSD, Recommended Vs. Actual

Rating kVA	Recommended kWh/lit	Actual kWh/lit
1450	3.84	3.2
1100	3.88	2.7
625	3.73	2.7
608	3.50	3.47
550	3.50	2.64
500	3.84	2.64
400	3.69	2.26
310	3.30	3.28-2.96
250	3.20	2.7
180	3.07	2.8-2
175	3.0	2.7
166	3.0	2.55
160	3.0	2.5
120	3.0	2.38

Table 2

Implications of Part-Load Conditions on Diesel Consumption

Rated Capacity	lit/kWh of HSD for Various Loading Conditions, %			
kVA	100	75	50	25
<100	0.2341	0.2404	0.2496	0.2617
320	0.2311	0.2388	0.2542	0.2750
1000	0.2301	0.2378	0.2531	0.2789

Source: Personal Communication, Kirloskar Cummins Ltd., New Delhi.

Lube Oil Conservation

Lubricating oils are consumed in large quantities by DG sets. An estimate by PCRA (Petroleum Conservation Research Association), calculates that around 10,000 MT of engine oils would be required in 1986-87 for consumption in DG sets alone. Although the quantity of lubes used, is much less compared to the HSD consumption, the price of lubes is nearly thrice as that of HSD. The consumption of lubes, depends largely on the number of hours for which a DG set is operated the speed of the engine, and the size. Lubes are to be changed, after a specified number of hours of operations.

Lubricating oil consumption is either due to top-up or oil change. Factors, which affect the top-up and oil change are given below:

Top-up

The top up oil consumption will largely depend upon:

- engine design - piston rings, clearances in valves, guides etc.
- engine operating condition - speed and load, frequent start/stops

One action to be watchful during top up operations is to avoid over lubrication. This leads to excessive viscous drag, and deposition of scales.

Oil Change

The useful life of lubricating oils is limited by the process of degradation and contamination. Degradation refers to an irreversible change in oil quality, e.g., oxidation. Contamination refers to a condition, where external unwanted agents have infiltrated into the oil.

Oil in service deteriorates due to degradation and contamination. At this stage, the oil charge has to be replaced by fresh charge. The general practice being followed is to drain the oil at predetermined intervals. The interval, being specified by number of hours of operation, by the equipment supplier. The oil change intervals for different DG sets are given in Table 3.

Table 3

Lube Oil Drain Intervals for Different DG Sets

Brand	Installed Capacity kW	Recommended oil drain interval in hours of operation
SKL	500	1000 •
SKODA	400	500
RUSSIAN	35	500
CUMMINS	400	250

Table 4

Tests Required for DG Set Engine Oils

Test	Test Method	
Kinematic Viscostity at 40oC	ASTM	D445
Kinematic Viscosity at 100oC	ASTM	D445
Viscosity Index	ASTM	D2270
Total Acid Number	ASTM	D974
Total Base Number	ASTM	D664/2896
Water	ASTM	D95
Pentane/Benene insolubles	ASTM	D893
Flash point	ASTM	D92

Source: Confederation of Engineering Industry (1987), Background Paper, "Workshop on Diesel Conservation in Captive Power Generation", New Delhi.

These specified intervals are based on the worst possible operating conditions and hence is a safe limit. If a user, operates under less severe conditions, and better maintenance practices, he is likely to discard oils when they are still good enough for use. Large scope exists for conservation of engine oil, if drain period intervals is optimized for their operating conditions or oil is drained on a condition basis.

To arrive at an optimum drain period, test the oil for its key properties. These properties, alongwith the test methods are shown in Table 4. To implement these physico-chemical tests, a small laboratory facility may be required. On the basis of the results, of the laboratory tests, decide whether to reduce, extend or keep the same drain interval. The cost of the facilities will pay back within a short time from the savings accrued due to longer oil drain periods.

Fuel Additives

Generally, fuel additives are used, only when a specific problem exists, and when other conventional solutions have been exhausted. Fuel additives have been mainly used in boilers, to improve combustion efficiency, inhibit high temperature corrosion, avoid cold end corrosion and formation of deposits. It is necessary to understand clearly, both the benefits and potential debits of the additives under consideration.

With special reference to fuel additives for improving combustion efficiency in DG sets, it may be noted, that results of preliminary tests conducted by Petroleum Conservation Research Association reveal that, out of thirty additive suppliers, who all claim improvements in combustion efficiency, only one brand of additive after use, has shown a slight improvement in the engine efficiency. The improvement is marginal, and efficiency of the DG set has increased by 2 per cent, in contrast to the manufacturers claim of 10-15 per cent.

Tests are still in progress to confirm the observed increase in efficiency. The effects of long term use of the additive, on the engine equipment has not yet been studied, and has to be checked for corrosion and fouling possibilities.

Waste Heat Recovery

DG sets operate in an efficiency range of 30-40 per cent. This shows that, of the 100 per cent energy liberated by the fuel, only 30-40 per cent is converted to electricity. The rest being lost as waste heat. The major sources of waste heat in a DG set are :

- Engine exhaust gases
- Jacket cooling water
- Lube oil cooling circuit

Various waste heat recovery equipments are available for the recovery of the otherwise wasted energy. The recovered waste heat could be used for a variety of uses. Some of the possible applications are listed below:

- Preheat combustion air for heaters/furnaces, near by
- Generate hot water for process
- Waste heat boiler for steam generation
- Vapour absorption system for refrigeration
- Preheating stock for furnaces

Waste heat recovery schemes become viable, only when there are large quantities of hot exhaust available and on a continuous basis, i.e., large capacity sets or a cluster of smaller capacity DG sets. However, it must be noted that these schemes will have a reasonable pay back, only if the DG sets are being run for a larger part of the year.

Maintenance Procedure

Strict adherence to recommended maintenance practices will ensure efficient operation of the DG sets, as well as save fuel. A check list of the important maintenance activities for DG set is provided below:

General

- Check for compression pressures and attend to stuck piston rings, leaky valves, excessive liner wear and ring wear etc., promptly.

- Meet manufacturers norms regarding parameters like cooling water, temperatures, back pressure, flow rate etc.
- Ensure cleanliness in the generator room.

Fuel Injectors

- Check injectors once in three weeks, for leakage and spray pattern

Exhaust Valves

- Frequency of overhaul depends on exhaust gas temperature and impurities in air and fuel

Starting Valve

- Ensure proper closing of the valve after start. Drain the starting air tank regularly to prevent corrosion and leakage of starting valve seat

Pistons/Piston Rings

Ensure proper cooling and lubrication; replace rings in time. Clear lube oil passages

Heat Exchangers

Clean once in every 500 hours of operation, if hard water is in use. Water pH to be between 7-8.

Turbo Charger

Breather to be cleaned externally once in an hour, and internal surface once in 100 hours of operation.

TIPS FOR FUEL ECONOMY

- Ensure proper storage and handling of fuel
- Try to load the set above 50% for large DG sets, and above 60 per cent for small sets
- Ensure proper fuel injection, correct viscosity (temperature), timing, proper mechanical condition of components, and prevent fuel and lube contaminants
- The cleanliness of air should be ensured by proper filteration; air filters should be cleaned regularly
- Select proper lubricant, monitor lubricant conditions, ensure proper lubricant cooling. Thicker oil causes 2 % excess fuel consumption
- Insulate exhaust piping to reduce air temperature inside the generator room
- Avoid exhaust gas temperature above 450 °C. High exhaust temperatures due to overload and restricted air supply, could lead to lower fuel efficiency as well as fouling of turbo-chargers
- Maintain the cooling circuit system efficiently, and clean heat exchangers regularly.

References and Material for further reading

- Confederation of Engineering Industry (1987), Background Paper, Workshop on, "Diesel Conservation in Captive Power Generation", New Delhi.
- Federal Energy Administration (1977), Waste Heat Management Guidebook Washington, U.S.A.

SHORT-TERM ENERGY CONSERVATION MEASURES AND ITS IMPORTANCE

Reading Material for
Training Programme on Energy Conservation
at Bharat Pumps and Compressors Limited
Naini, Allahabad
January 7-8, 1988

HANAGUDU HARISH
Tata Energy Research Institute
7, Jor Bagh, New Delhi 110 003

SHORT-TERM ENERGY CONSERVATION MEASURES AND ITS IMPORTANCE

The Inter-Ministerial Working Group in 1983, in their report estimated that as much as 25 per cent of energy consumed in industry could be saved through various conservation measures. Preliminary estimates reveal, that around 15 per cent of energy consumed in industry today, can be saved by short-term measures such as better housekeeping, improved insulation, additional instruments, tighter process control, etc.

Good housekeeping measures require negligible or no capital investment but nevertheless have a sizeable and significant impact on energy consumption in the plant.

Short-term measures require minimal capital investment. Recovery of investment is around six months to a year, and energy savings are around 10% - 20%. The emphasis is on efficient housekeeping, tighter process control, stricter operating norms, better maintenance practices, prevention of leaks, improved insulation etc.

In a wide range of areas, it only requires meticulous adherence to Do's and Dont's in the plant operators manual. It makes good sense to begin with better house keeping for it results in fast and tangible results not only in conserving energy but also an improvement in the productivity. The visible benefits have the additional advantage of psychologically and attitudinally preparing the managers and workers to adopt intensive energy conservation measures. The claim by all industries reluctant to the introduction of systematic energy auditing is that all common sense areas for energy conservation have long since been detected and rectified. This has always proved wrong, and in almost all cases there has been additional benefit to be accrued.

The issues related to short term energy conservation measures are given below:

Motivate Workers

Good housekeeping can neither take off nor yield results unless the plant workers are properly motivated towards it. Schemes of motivation and interest should be introduced to create interest and commitment among the workers

Instrumentation and Measurement

Adequate instrumentation is extremely important and an absolute necessity to perform detailed energy use studies or as a follow up to monitor conservation programmes. In many industries, there is a general lack of instruments to measure energy flows and other parameters like pressure, temperature, humidity etc. Investment in energy metering and process instruments, is bound to yield returns because effective management can only follow sound measurement.

Energy Systems Maintenance

Energy systems maintenance is the maintenance of all systems that use or affect the use of energy. Energy systems maintenance includes, such routine maintenance tasks as lubrication, examination and cleaning of electrical contacts, calibrating instruments, but also includes such non-routine tasks as repainting walls to increase the effective lighting, cleaning fins on compressors, etc. Proper maintenance of the plant and machinery is a key factor in determining the efficacy of the energy conservation programme. A good energy systems maintenance programm can save a company substantial amounts of money in wasted steam, wasted electricity, and in lost production and additional expense caused by preventable equipment breakdown.

There are four steps in the development of a maintenance program.

Step 1, is to determine the present condition of the existing facility. The output will be a list of motors, lights, transformers, furnaces and other components that make up such a system, together with a report on the condition of each.

Step 2, is the preparation of a list of routine maintenance tables with an estimate of the number of times each task must be performed. This list should also include, for each task, the skill, the material needed, and the appropriate equipment.

Step 3, Data from Step 2 would be incorporated into a regular schedule for the accomplishment of the desired maintenance.

Step 4, is the monitoring necessary to keep the programme in force once it has been initiated.

Summary - Housekeeping Recommendations

Table 1, provides a list of energy saving measures applicable to engineering industries. Table 2 lists the housekeeping and maintenance recommendations to increase energy efficiency in engineering industries.

Table 1

List of Energy Conservation Measures - Engineering Industry

Specific Conservation Measures
Better fuel handling and preparation practice
Improved combustion and draft control
Use of low excess air burners
Better control of furnace atmosphere
Better utilization of hearth loading
Minimising radiation losses through openings and walls
Retrofitting heat recovery devices
Provision of good quality refractory/insulating bricks
Application of ceramic fibre insulation in batch-type furnaces
Modifying furnace design
Conservation of electrical energy through load factor, power factor ,etc.
Replacement of inefficient furnace by more efficient furnace.

Table 2

Housekeeping and Maintenance Recommendations for Engineering Industries

Subject/Name of Equipment

1. Insulation

- Insulate valves, flanges and fittings both for hot and cold pipe lines
- Evolve procedures for removing insulation to allow access to pipe, and replacing the same insulation
- Hire insulation manufacturer, to visit site, evaluate existing insulation and replacement practices and recommend changes.

2. Boilers

- Periodically clean the inside and outside surfaces of boiler tube
- Monitor flue gas composition and temperature regularly and take corrective action
- Measure the TDS level in the boiler drum and adjust quantity of blowdown
- Maintain proper excess air levels.

3. Furnaces

- Investigate possibilities of using recovered waste heat to preheat combustion air, or to generate heat for the plant
- Repair faulty insulation, especially around apertures and bends
- Ensure that door seals are efficient
- Adjust and maintain burners for efficient operation
- Check for constant correct fuel and air pressure

- Monitor for correct fuel/air ratio by analysis of stack gases
- Install dampers; check that they function correctly
- Ensure burners are correct size for duty required.

4. Cooling Tower

- Ensure regular bleeding of water from the cooling tower to prevent concentration build up of scale forming salts
- Determine time interval of bleeding by monitoring hardness of cooling tower water at the discharge end.

5. Heating Process

- Ensure that ovens and heaters are fully utilized i.e., try to avoid part loading
- Shut down heaters when not in use
- Reduce operating time to that actually required
- Ensure holding temperatures are the minimum necessary and closely controlled.

6. Electrical Equipment

- Check the size of electric motors for peak operating efficiency
- Provide proper maintenance and lubrication for motor-driven equipment
- Reduce transformer losses by de-energising when possible
- Keep busbars as short as possible; joints should be clean and sound
- Switch off electrical equipment when not in use
- Use higher voltage where possible to reduce transmission loss
- Constantly monitor power factor of whole plant and correct when too low

- Monitor Maximum Demand on electricity & reduce wherever possible
- Meter energy consumption at all significant load/equipment

7. Air-conditioning

- Turn off out of working hours
- Turn off 1/2 - 1 hour before work place is vacated
- Replace filters in the ducted air system regularly
- Clean extended surfaces of the cooling coils periodically
- Keep the ductwork clean.
- Use sun screens wherever possible

8. Compressed Air

- Eliminate leaks in distribution system
- Clean inlet air filters and compressed air filters regularly and replace them periodically
- Remove unnecessary lines to eliminate potential leaks
- Install adequate dryers on airlines
- Install compressor air intakes in coolest possible locations
- Reduce compressed air pressure to the minimum required
- Use filters for cleaning air prior to intake
- Use waste heat from compressors as space heat
- Renew valves, rings and glands on compressors regularly

9. Lighting

- Keep windows as clean as possible
- Install timers on light switches in little used areas

- Convert to fluorescent, sodium or multi-vapour direct lighting where possible

- Use photocell control on outdoor lights

- Keep lighting fixtures clean

- Turn off lights on days when natural light is sufficient

- Appoint someone in each area to make sure that lights are only on when necessary

References and Material for Further Reading

- Turner, W.C. (Ed), "Energy Management Handbook"

- CEC, Report EVR-8813-EN, "Increasing Energy Efficiency"

- NIFES, "Fuel Economy Handbook", London

- National Productivity Council (1987), Background paper on Energy Audit, at the "Workshop on Empanelling Energy Auditors", New Delhi.

REFERENCES

Andreas, J.C. (1987), Energy-Efficient Electric Motors, Marcel Dekker, New York, (1982).

Chiogioji, Melvin, H. (1979), Industrial Energy Conservation Marcel Dekker, Inc., New York.

Rao, A.N., Jagadeesan, R.R., Energy Conservation by Power Factor Improvement in a Manufacturing Industry.

Reay, David, A. (1979) Industrial Energy Conservation, Pergamon Press Ltd., Oxford.

Srinivasan, P.R. et al. (1979), Fuel Efficiency in Industrial Practice, Asian Productivity Organization, Tokyo

Talbott, E.M. (1986), Compressed Air Systems. A Guidebook on Energy and Cost Savings, The Fairmont Press, Inc., Georgia

Trinks, W & M.H. Mawhinney, Industrial Furnaces (Vol. I & II), John-Wiley & Sons Inc., U.S.A.

Turner Wayne C.Ed (1982) Energy Management Handbook, John Wiley & Sons Inc., U.S.A.

Virendra S. Kothari, Strategies for Improving Efficiency of Electric Motors in Industry and Agriculture

Werninck, E.M., (1978), Electric Motor Handbook, McGraw Hill U.K.

ENERGY CONSERVATION BY INDUCTION HEATING

Satish Sabharwal
Tata Energy Research Institute
7, Jor Bagh
New Delhi

Training Programme on Energy Conservation

Bharat Pumps and Compressors Limited

Naini, Allahabad

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A. Introduction

Traditionally metals were heated with oil, gas or resistance heating. Recently induction heating has been preferred method to certain metallurgical industries. The principle of induction heating essentially consists of introducing the source metal in an alternating magnetic field. The alternating magnetic field causes electric currents like eddy currents in transformer by Faradays law.

$$V = L \frac{d\phi}{dt}$$

Induced voltage = inductance x rate of change of flux .

Without iron core considerably large reactive current is required to generate same flux level. Though in ordinary transformers power frequency of 50 cycles/second (HZ) is used, a higher frequency will increase the rate of change of flux. Also as the frequency increases the heating is more towards the surface i.e., depth of penetration is reduced. Also the workpiece is heated more near the coil for example in case of steel the pemeability changes drastically near curie point.

This paper summarises some of the salient points of induction heating.

B. Induction heating elements

The induction heating consists of following elements induction coil, power supply, and control system.

1. Induction Coil

Each workpiece shape, volume and material requires a special coil design in other words the oil has to be tailor made to user's requirement.

2. Power Supply Equipment

The power supply equipment consists of a suitable frequency converter according to the workpiece and the heating problem to be solved. Some of the major ones are

- Rotating frequency convertor	medium frequency	500 to 10,000 HZ
- Static frequency converter	medium frequency	3,000 to 20,000 HZ
- Radio frequency generators	high frequency	350 KHz to 5 MHZ

C. Application of induction heating

The main advantages of induction heating as against oil, gas or electric heated furnaces are :

- Short heating time and therewith minimum building of scale and high production rate.
- Precise heating zone at partial heating
- Fast and precise regulation of temperature
- No preheating time
- Small space requirements
- Any desired level of automation possible

Some applications of induction heating are described below:

1. Induction Soldering

Soldering is a method to join two metallic workpieces by means of solder with a lower melting temperature than the workpiece material.

Satisfactory results can only be achieved if:

- The surfaces to be joint are parallel and have a sufficient section
- The gap is approx. 0.1 mm
- The surfaces are free of grease and have a metallic shine
- The joining surfaces are wet with flux (if flux is prescribed) so that all remaining oxidation is removed.

In view of the short heating time with induction, the soldering temperature is reached in a fraction of time compared with flame - or furnace - heating and in most of the cases the application of protective gas against oxidation is not required. Another advantage of induction heating is that any desired temperature can be reached with the same installation which allows to utilize different solder according to the production procedure.

If the use of protective gas is unavoidable, the inductor can be combined with a protective gas spray or soldering takes place under a protective gas shade.

2. High frequency tube-welding

Continuous welding of tubes formed from strip by induction heating and welding are today widely used in view of their economic production at low cost. This heating method takes full advantage of the fact that two opposite currents attract each other so that in this case the heating is concentrated along the edges of the strip to their junction point where the temperature necessary for welding is reached. This effect is further increased by using a magnetic core (impeeder) inside the tube to reduce the magnetic resistance. The tube edges are pressed together by rollers the bur which forms along the weld is removed and the tube is cooled and cut to length.

With this method, tubes made of steel, brass and aluminium can be welded. High quality tubes where hard zones may occur after cooling, are reheated up to 950oC, normalized with the help of a line inductor and subsequently slowly cooled. The purely inductive HF - energy transmission is contactless with no wear and no marking of the tube surface. However, when changing to different tube - or section sizes, the inductor must also be changed.

An other method, the so called conductive transmission, uses special rolling contacts to transmit the HF-energy which can be easily adjusted to various tube sizes. The life of the contacts is however restricted. In view of the high contact pressure, this method is used for large tubes with great wall thickness. The high power HF - Generators required for tube welding with outputs up to 700 kW and frequencies from 200 to 500 kHz are gradually used. Their design is based on many years of experience and on close cooperation with tube mill manufacturers.

INSTALLATION AND MAINTENANCE PRACTICES OF MOTORS FOR ENERGY CONSERVATION

Satish Sabharwal
Tata Energy Research Institute
7, Jor Bagh
New Delhi

Training Programme on Energy Conservation

Bharat Pumps & Compressors Limited

Naini, Allahabad

January 7-8, 1988

INTRODUCTION.

This paper presents in brief the salient factors to be considered for installing and maintenance of motors. The motor ca starts when it is received by consumer.

1.0 Receipt and Inspection:

1. The machine should be removed carefully from its packin and examined to see that no parts are broken.
2. After unpacking the machine should be cleaned to remove all dust and remnants of packing material and oil parts
3. If motor is not to be installed immediately it should b stored in a dry sheltered position.

1.1 Insulation resistance/Winding Resistance Measurement.

1.0 A Megger should be used for testing the insulation of motors stored in for long or has become damp.

An approximate formula used is

Minimum insulation = (Rated voltage/1000) Mega ohm

A better method would be to take regular reading and periodic readings recorded and their changes observed.

This is recessory to find any electrical leakages. Also resistance can be measured between phases and if they are n identical within limits then there is unbalance in electric circuit and it should be investigated.

2.0 Care of Bearings:

1) No machine fitted with roller bearings should be allowed to stand on a vibration floor during storage or operat if this can be avoided.
2) Ball bearings are much less suceptible to damage by stationary vibration, but this should not allowed to encourage carelessness in handling or storage.
3) These ensure that functional losses are maintained at low level and hence efficiency is more for such a case.

Location:

1.0 Before installing any machine, it is essential that the regulation laid down by Mines Act, the Factory Act or other Government or Municipal Regulation and Rules of Insurance Company.

2.0 The machine should be placed in cool and well ventilated position and care should be taken to provide an unrestricted outlet for the air discharged from the motor. This ensures insulation strength and prevents informal short circuiting.

4.0 EARTHING:

1.0 The frances of all motors should be securely earthed by a method that is electrically and mechanically Sound. Reference should be made to IS: 900-1956 section 4.3.3 & 10.4 for detailed information.

This ensure there is not electrical leakage and therefore electrical efficiency is maintained at manufacturer standard.

5.0 FOUNDATION:

1.0 When mounting at floor level, the machine, its bedplate or its slide rails shoul be securely bolted to a solid and level foundation.

2.0 A good foundation concrete consists of 1 part cements, 2 parts sharp sand and 4 parts broken stone.

6.0 THE LEVELLING AND GROUNTING OF BED PLATES:

1.0 Levelling of bad plates should be performed before grouting.

2.0 For larger motors which are mounted on bed plates it is preferable to have several steel girders sunk into foundation in order to reinforce the concrete.

7.0 BELT DRIVES:

1.0 A belt should be sufficiently light to carry the load without flapping as this is dangerous and also results in a noisy drive. On the other hand excessive belt tension invites bearing trouble or shaft failure and is responsible for uneven running and a short belt life. Sliding bed plates should be ordered when a belt drive is used. Proper belt tension will ensure minimum mechanical power transmission losses.

3.0 Alignment of Drive:

For machines directly coupled with flexible couplings there three options.

1. Axial Positioning of shafts.
2. Paralleling of shafts.
3. Centring of shaft axes.

Proper alignment ensures less transmission losses and greater efficiency.